IPID4all Doctorate Research Exchange with DLR Institute of Networked Energy Systems (Carl von Ossietzky Unversität)
Feedback report

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Redox Flow Batteries

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Introduction

For more than two hundred years the rapid development of industrial societies has relied on the exploitation of huge reserves of fossil fuels. Resources formed over hundreds of millions of years have been burned in a relatively short time, with substantial environmental impact. Nowadays, traditional fossil fuels are trying to be substituted for other renewable energy sources, due to the negative environmental effects caused by these non-renewable sources. However, the renewable energy sources are intermittent and unpredictable, making the use of energy storage systems necessary. In this point, Redox Flow Batteries (RFBs) have received much attention in the last years, due to their promising use for stationary energy storage. The most appealing features of this technology are: scalability and flexibility, independent sizing of power and energy, high round-trip efficiency, high depth of discharge, long durability, fast responsiveness and reduced environmental impact. A RFB is an electrochemical device in which chemical energy is converted to electricity and vice versa by oxidation/reduction of electrolytes employed. There are many types of redox flow batteries that can be classified by their active species, their solvent and by the form of their active materials (liquids, solids and gaseous). One of the most promising types of this technology is the vanadium redox flow battery (VRFB), which operates using a vanadium solution in both electrolytes that contain two redox couples, V^{+4}-V^{+5} and V^{+3}-V^{+2}, which are the real energy storage systems. This type of redox flow batteries shows low cross-contamination problems and the cell capacity does not decrease with time which can increase the time life of the battery. VRFB usually works using a selective ion exchange membrane as an ion conductive medium. The huge cost of this type of membrane is the main disadvantage of this type of technologies. The used electrodes are typically carbon-based materials, such as carbon or graphite felts, carbon cloth, carbon black, graphite powder and so on. These materials have good potential in terms of operation range, a good stability and a high reversibility. Besides, these inert electrodes present lower costs than other ones used in other energy devices like fuel cells. Nevertheless, the search of new materials (membranes, electrodes and electrolytes) which can improve the efficiency of this technology is necessary.

Research Undertaken

During the three months in the facilities of DRL Institute of Networked Energy Systems (former NEXT ENERGY), the behaviour of different membranes in a redox flow battery was studied. Nafion and PBI were the selected membranes. First of all, the through plane conductivity of both membrane types was studied in an H-cell with four electrodes. Secondly, the performance of these membranes was evaluated in a cell with 25 cm^2 of active area. Charge and discharge cycles were carried out at different current densities (40, 48, 60, 72 and 80 mA cm^{-2}) and constant power. The voltage and the open circuit potential (OCP) were monitored during the charge and discharge cycles. The charge and discharge capacity, as well as the voltage, columbic and energy efficiencies were calculated in order to determine the cell performance. Impedance measurements were also carried out to evaluate the cell resistance as a function of the used membrane.

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The electrochemical analyses were carried out with a potentiostat/galvanostat (Solartron Analytical Modulab Pstat potentiostat/galvanostat). Carbon felts thermal treated (400 °C, 18 h) with 5mm of thickness were used as cathode and anode. Graphite and copper plates were used as bipolar plates and current collectors, respectively. A commercial solution of 1.6 M of $VOSO_4$, 2M of H_2SO_4 and 0.05 M of H_3PO_4 (OXKEM) was used as electrolyte in both compartments.

Finally, a physical-chemical characterization was carried out to the bipolar plates to evaluate their degradation after a high number of charge-discharge cycles (differential scanning calorimetry, confocal microscopy and in-plane conductivity analysis).

The results showed a reduced cell performance with PBI membrane. The low PBI conductivity raises the cell resistance and decreases its performance. Simultaneously, the high crossover of the Nafion membrane decreases the coulombic efficiencies and leady to fast capacity fading. However, this membrane showed higher voltage efficiencies, due to the higher ion conductivity. In addition, ageing was not observed in the bipolar plates after the charge-discharge cycles.

Personal Experience

The IPI4all-programme is a huge opportunity to PhD students. It gives the chance to know and work with other research groups in a different country. Carl von Ossietzky University helped me before and during my stay in Oldenburg with all my questions and problems. I could acquire a lot of knowledge related to the redox flow batteries and a different way to see the research. The Fuel Cell Division of DLR Institute of Networked Energy Systems is a large group of people from different countries and working with them allowed me to know great professionals and people. In addition, this internship gave me the opportunity to improve my English skills and start to learn German language.

Regarding the city, Oldenburg is a calm and beautiful city, full of nature and nice people. Everybody rides bikes to anywhere but there is a good public transport too. It is also easy and comfortable to stay there due to the low cost canteens.

The only negative point was that the stay time was too short and I had not enough time to perform all experiments I wanted to do. However, I would recommend this experience to everyone because the program is a great opportunity to open your mind.

Conclusions

The research exchange was a great opportunity to start my research in Redox Flow Batteries due to the DRL Institute of Networked Energy Systems count on a large group of high quality researchers. I enjoyed a lot the three months in Oldenburg. It was a great personal and professional experience for me.

Outlook

Both institutions have worked together on a project and this internship is a good way to continue to collaborate. The good results achieved this year and another one before with the IPID4 all programme give us the chance to send new PhD students the following years.

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