

The International Flow Battery Forum 2017

A wide range of topics were covered from academic studies to challenges faced in industry

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Introduction

The Eighth International Flow Battery Forum, organised by Swanbarton Ltd, UK, focused on industrial applications of redox flow batteries (RFB). The conference was held from 27th to 29th June 2017 at the Mercure Piccadilly Hotel, Manchester, UK. It was attended by 212 delegates from all over the world, including flow battery developers, material and component suppliers and academics.

The conference covered both the vanadium redox flow battery (VRFB) – the most mature technology – and alternative chemistries including organic redox flow batteries (ORFB). It celebrated the increasing number of large-scale flow battery installations to date. As renewables such as wind power and photovoltaics (PV) play an increasing part in energy generation worldwide, the need for storage of electricity becomes crucial. Flow batteries are well suited to this application, particularly when storage for multiple hours is required. Throughout the conference, there was a focus on further commercialisation of RFB technology and what is needed to achieve this. All participants saw the need to further promote understanding of the benefits of flow batteries amongst energy storage system developers and investors.

The conference opened with a keynote address by the developer of the VRFB, Professor Emeritus Maria Skyllas-Kazacos (University of New South Wales (UNSW), Australia). She gave an overview of the various flow battery chemistries, the status of their commercial installation and outlined the Battery Storage and Renewable Energy Fund in South Australia. Her talk was accompanied by plenty of lively discussion and questioning.

Jonathan Radcliffe (Birmingham Energy Institute, UK) spoke about the need for decarbonisation of energy, particularly heating and cooling. One of the proposed solutions is electrification; he spoke about the ‘value of flexibility’ in electricity storage. The biggest cost benefits will be for longer duration storage and RFBs are a candidate for this.

Vanadium Redox Flow Battery

The first morning focused on recent progress in the flow battery industry and its prospects for further commercialisation. Presentations were given by several companies commercialising VRFBs. Scott McGregor (RedT, UK) is targeting the renewables market and regards a flow battery as a machine for energy storage, offering multiple stacked services and heavy use, rather than a battery (provision of power, infrequent use for a single application). Sumitomo Electric Industries, Ltd has been developing VRFBs for over 30 years; Toshikazu Shibata (Sumitomo Electric Industries, Ltd, Japan) presented performance data for its 15 MW/60 MWh demonstration plant in Hokkaido, Japan. This plant is integrated with a large PV installation, it was started up in 2015 and is able to achieve both frequency regulation and longer

duration renewables integration. Peter Fischer (Fraunhofer ICT, Germany) gave an update on the project RedoxWind, which will link a 2 MW/20 MWh VRFB with a 200 kWh lithium-ion battery and a wind turbine.

Xiangkun Ma (Dalian Rongke Power Co, Ltd) described the construction of its 200 MW/800 MWh demonstration plant on the Dalian peninsula, China. The first phase (400 MWh) was due for completion end-2017. The factory has capacity for 300 MW year⁻¹ stack manufacturing capacity; all electricity used during the production process is from PV. Professor Dr Huamin Zhang (Dalian Institute of Chemical Physics, Chinese Academy of Sciences, China) described further developments by Rongke Power and the Dalian Institute of Chemical Physics which included a non-fluoride ion conducting membrane with very good capacity retention, improved bipolar plate technology and high power density stacks.

Liyu Li (UniEnergy Technologies (UET), LLC, USA) presented a competitive value proposition for VRFB compared to Li-ion. He demonstrated the increased cycle life of VRFB compared to other battery technologies and showed how the economics of VRFB improve at longer charge/discharge durations, making them particularly suitable for renewable energy integration. UET is using mixed hydrochloric/sulfuric acid electrolytes developed at Pacific Northwest National Laboratory, USA.

Mianyan Huang (Pu Neng, China) described a proprietary engineered plastic membrane with low permeation rates, high efficiency and low cost. The membrane will be used in a prototype VRFB at 500 kW scale in 2017. Both Li and Huang agreed that growth in the renewable energy storage market is led by China. In 2016, 15% of total wind energy and 20% of PV generation were curtailed; an opportunity for storage.

Lars Moellenhoff (Glex Energy Storage (formerly Gildemeister), Germany) highlighted that the key hurdle for developing RFB projects is to convince investors to think beyond the 5–10 years typical of the energy storage industry and to consider the total cost of ownership (TCO) benefits. GLex's positioning as an integrated, independent power producer should help to overcome this.

Energy Density

RFBs for energy storage are generally housed in containers of limited volume; hence it remains important to maximise the energy density of the vanadium electrolyte solution. Professor Emeritus Skyllas-Kazacos described work in her group to develop additives to prevent precipitation

of vanadium salts. A 2 M vanadium electrolyte solution is stable to precipitation between 15°C and 40°C; decreasing the vanadium concentration to 1.6 M increases the stability window but decreases the energy density. Inorganic additives developed at UNSW have allowed the use of 3 M vanadium solutions with increased energy density and without significant precipitation.

Vanadium Supply Chain

Terry Perles (TTP Squared, Inc, USA) presented supply and price data for vanadium and noted that three quarters of the global vanadium supply is as a coproduct of steel slag. Alberto Arias (Arias Resource Capital (ARC) Management LP, USA) highlighted that vanadium is the largest cost component of a VRFB and that price volatility is a major challenge in their widespread deployment. Arias proposed that a vanadium leasing model, where a financial intermediary maintained title to the vanadium, could help reduce the upfront capital expenditure (CAPEX) and smooth out vanadium volatility risks.

Safety

Jonathan Buston (Health and Safety Laboratory, UK) talked about safety issues in the battery industry. RFB resemble chemical plants and face standard chemical engineering challenges of process and heat control. Additional complexity comes from the integration of the RFB control system with the National Grid control system.

Technical Issues

Dr Fikile Brushett (Massachusetts Institute of Technology (MIT), USA) probed pore-scale mass transport in RFBs and its effect on the performance of the system. He looked at different reactor scales and developed a way to use a smaller reactor which replicates the flow of a larger system.

Component Development for Flow Batteries

Thorsten Seipp (volterion GmbH, Germany) presented the development of fully welded stack technology. Continuous graphite plates are welded onto thermoplastics, giving a compact new stack design with very thin (<2.5 mm) half cells. The smaller, thinner stack allows material savings and automated production.

Jan Girschik (Fraunhofer UMSICHT, Germany) is developing a continuous process for making

extra-large bipolar plates. The requirement for a bipolar plate is that it is liquid- and gas-tight, corrosion and chemical resistant, with high conductivity and mechanical stability. Low cost is also an important feature.

Organic Redox Flow Batteries

There were several presentations on ORFBs. This technology has attracted interest because the organic electrolyte offers the potential of significantly lower capital cost compared to vanadium systems. In a keynote lecture, Professor Michael Aziz (Harvard University, USA) described quinones and other electrolytes for aqueous organic RFBs. In principle, low cost organic electrolytes with a shorter lifetime could be replaced periodically and still offer a low cost solution.

Thibault Godet-Bar (Kemwatt, France) is making prototype ORFBs and plans to build an industrial scale, 200 kWh ORFB in 2018. It has identified a low-cost, readily scalable organic electrolyte and achieved 7000 cycles. Its cost target is US\$300 kWh⁻¹ in three years' time.

Steven Reece (Lockheed Martin Energy, USA) noted that design for low cost must be approached from the system level. The Lockheed Martin system offers a tuneable metal-ligand electrolyte, an ion-selective membrane with low crossover and optimised stack design. The chemistry is based on earth-abundant transition metals and easy-to-synthesise ligands.

Other Chemistries for Flow Batteries

Natalia Mazur (Elestor, The Netherlands) described next generation flow batteries based on the HBr/Br₂ couple. Bromine complexing agents are

added to increase the safety and the energy density of the electrolyte but they reduce the performance of the membranes. Elestor has investigated the use of competing ions, different operating conditions and regeneration of the membrane.

Pekka Peljo (École polytechnique fédérale de Lausanne (EPFL), Switzerland) described a copper-acetonitrile (Cu-ACN) RFB which can be charged by electricity or low-grade heat (~100°C), see **Figure 1**. Replacing water with propylene carbonate electrolyte solvent helps maintain the cell voltage at 1.3 V.

Ian Whyte (WhEST, UK) has developed generic flow battery stack technology for use with a range of battery chemistries, for example an iron-ferricyanide system. Michael Tucker (Lawrence Berkeley National Laboratory, USA) described a low-cost all-Fe flow battery for use in, for example, mobile phone charging and emergency lighting in the developing world. The electrolyte is a non-toxic disposable iron solution.

Conclusions

This very interesting conference covered the whole spectrum of topics, from academic studies to challenges faced in the further commercialisation of flow batteries on an industrial scale. Much of the conference focused on longer duration (multi-hour) energy storage for integration of PV and wind energy. In order to compete with technologies such as Li-ion, capital cost reduction remains a key focus.

Reference

1. P. Peljo, D. Lloyd, N. Doan, M. Majaneva and K. Kontturi, *Phys. Chem. Chem. Phys.*, 2014, **16**, (7), 2831

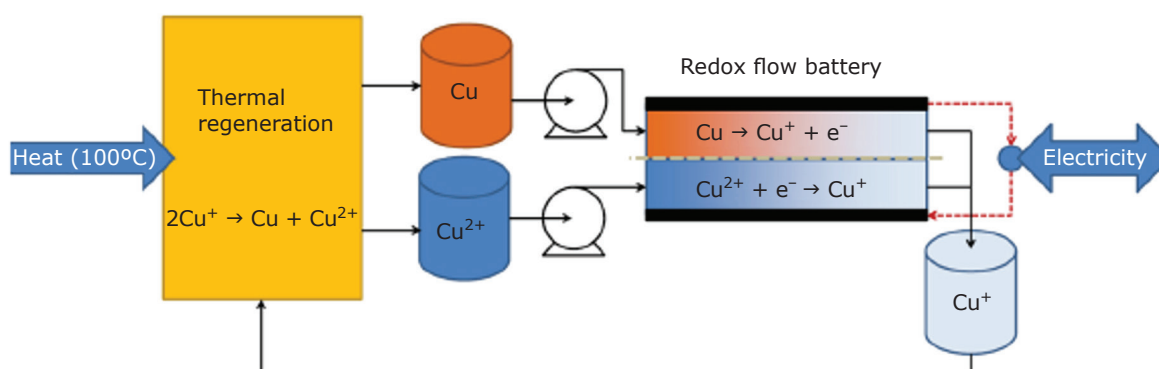


Fig. 1. Schematic of the Cu-ACN system (Reproduced from (1) with permission of the PCCP Owner Societies)

The Reviewers



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