Development of alternative rebalancers for the ICRFB

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INTRODUCTION

South Africa (SA) is the world's largest ferrochrome producer and has a high Global Horizontal Irradiance (GHI). The ferrochrome industry uses a significant portion of SA's generated electricity while also being one of the largest contributors to its GDP[1]. However, SA's national electricity provider is under significant strain. This has led to frequent power cuts which threaten the ferrochrome industry and consequently SA's economy. Considering its high GHI and centralized rural power consumption, SA is most suitable for off-grid solar power. To counter the intermittency of solar energy, large scale energy storage is required. The iron-chromium redox flow battery (ICRFB) is an excellent contender for this application.[2] However, it suffers from significant capacity decay due to side-reactions (notably the hydrogen evolution reaction)[2]. It was therefore the aim of this study to develop a rebalancing method for the ICRFB that addresses the shortcomings of current rebalancing methods. A modification of Wei and Li's hybrid chemical-electrochemical rebalancing method[3] was investigated as well as a direct Fe^0 chemical rebalancing method[4].

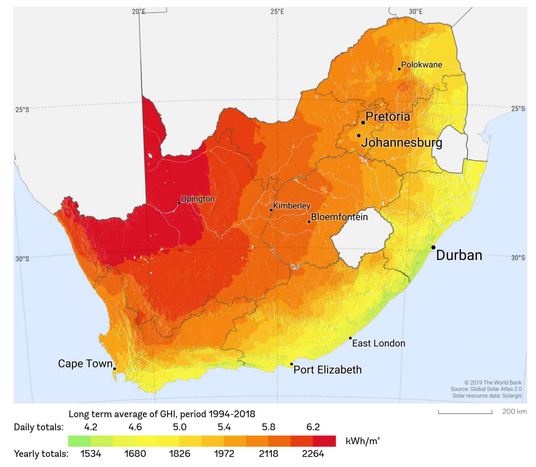

Figure 1. Long term average of the global horizontal irradiation (GHI) for SA between 1994 – 2018.

METHOD

Hybrid rebalancer

- Rebalance cell (RBC) loop
  - Add RBC loop to RFB as in the figure
  - Simulated 100% imbalanced catholyte for RFB
  - RBC electrolyte with Fe2+ as rebalancing species
  - Rebalance catholyte

RBC electrolyte recovery

- Reduce Fe3+ in RBC electrolyte
  - Organic reducing agents: Stir at 50°C for 24 hours
  - Fe0 powder: Stir at 25°C for 15 min

Direct Fe0 rebalance

- Add Fe0 directly to RFB catholyte to reduce Fe3+
  - $Fe^0 + 2Fe^{3+} \rightarrow 3Fe^{2+}$
  - Restore [Fe] by adding $CrCl_3$ in HCl

MONITOR WITH DEVELOPED UV-VIS METHOD

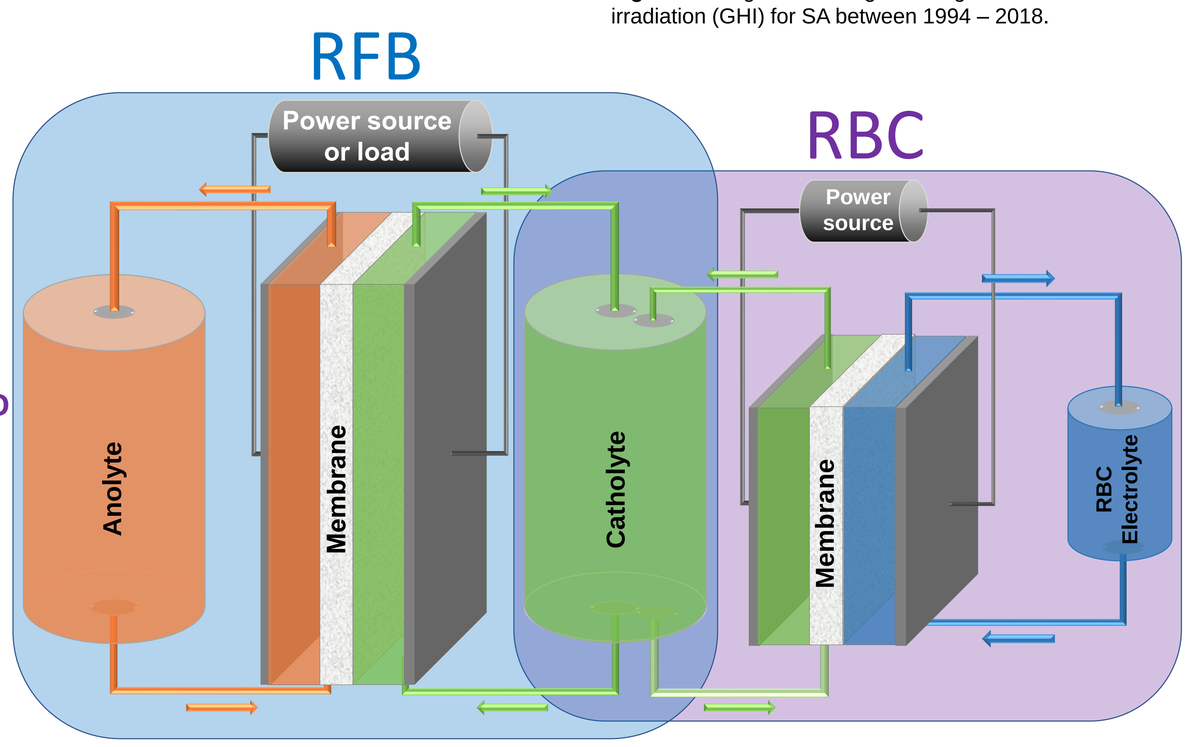

Figure 2. Schematic illustration of a redox flow battery (RFB) with hybrid RBC

RESULTS

Hybrid rebalancer

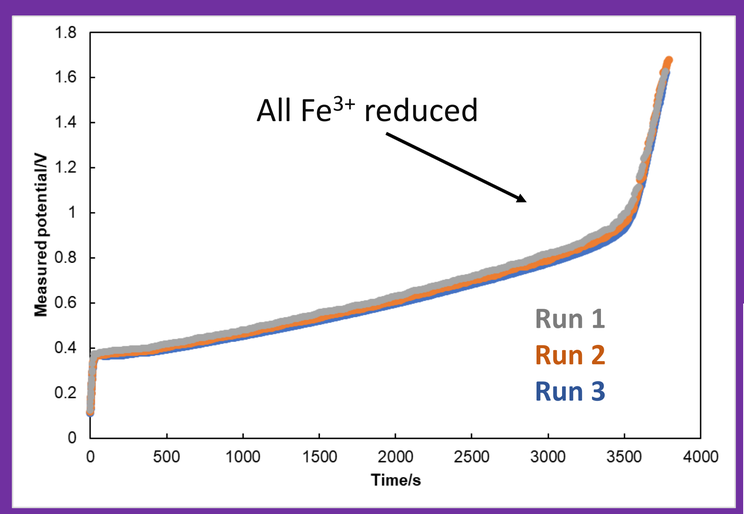

Figure 3. Hybrid rebalance cycles at 40 mA/cm², 25 °C and 50 mL/min with N212 as separator

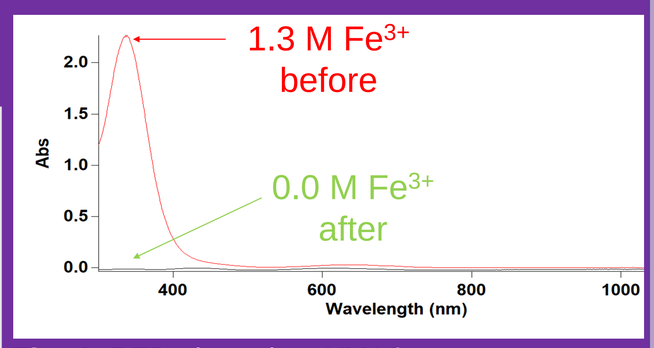

Fig. 4: RFB electrolyte UV-Vis spectra

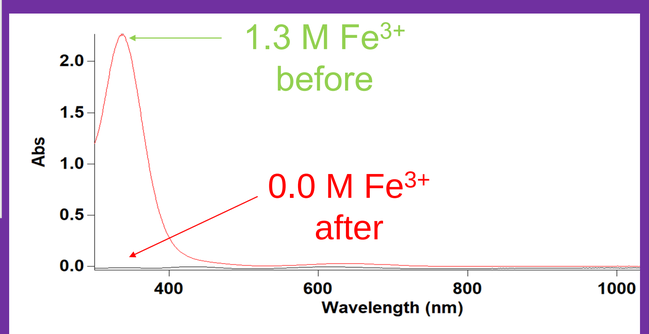

Fig. 5: RBC electrolyte recovery with Fe^0

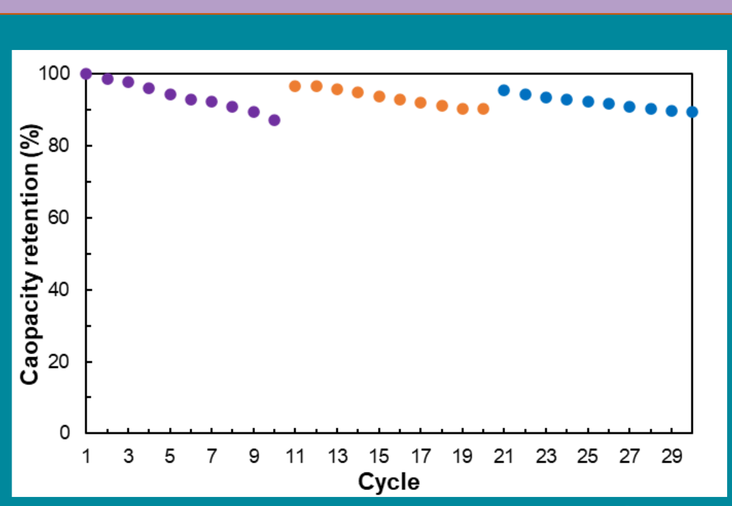

Figure 6. Capacity restoration using direct Fe^0 method

Direct Fe^0 rebalancing

+ Capacity restored with hybrid and direct Fe^0 methods
- Spent hybrid RBC electrolyte only recoverable with Fe^0
- Fe^0 can be used directly in RFB
  - ✓ Reduced complication and cost
  - × Continuous electrolyte production

CONCLUSION

The aim of this study was to develop a rebalancing method for the ICRFB that addresses the shortcomings of current rebalancing methods. To this end, a modification of Wei and Li's hybrid chemical-electrochemical rebalancing method was investigated as well as a direct Fe^0 chemical rebalancing method. Both methods showed excellent capacity restoration. However, the hybrid method suffers from difficult spent electrolyte recovery and the direct Fe^0 method suffers from continuous electrolyte production. Future work will therefore entail the investigation of alternative recovery methods for the spent rebalance electrolyte in the hybrid system.

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