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Design of Semi-Solid Flow Batteries

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The purpose of this research is to create a design and analysis process to aid in the design of scalable, manufacturable, cost-effective semi-solid flow cell (SSFC) batteries. SSFCs are rechargeable and use energy-dense, semi-solid, flowable electrochemical slurries in a system that decouples energy from power [1,2]. Designers using this process will be able to create SSFC vehicle and grid storage batteries with the minimum cost and maximum gravimetric and volumetric energy densities. This design process is a stepping stone in the realization of long range (goal is 500 miles) electric and hybrid electric vehicles. Such vehicle batteries will facilitate reduction of U.S. transportation sector's reliance on petroleum-based fuels. Grid storage batteries designed with this process will allow expanded incorporation of more renewable power sources into the grid. A proof-of-concept SSFC has been fabricated and tested to validate the efficacy of the proposed design process.

The designer uses the proposed design and analysis process by inputting (i) a desired battery power and feasible C-rate and (ii) rheological and electrochemical properties of the anode and cathode slurries. The analysis tool then outputs specifications for battery parameters such as casing wall thickness and unit cell shape and layout. A unique parameter for SSFCs is plug count. Unlike conventional cartridge battery designs, SSFCs can (dis)charge a selected part, or plug, of the available electrochemical material in the battery. As one plug is fully (dis)charged another plug replaces it from a storage tank.

The cost per unit energy as a function of the number of such plugs is illustrated in Figure 1. This energetic cost includes the cost of slurries, membrane, current collectors, and structural casing. The presented data does not represent a complete optimization of an SSFC but is an example of how the analysis tool can aid in the design process. Increasing the number of plugs in a cell reduces the cost of the cell by decreasing the amount of current collector and separator membrane material. The energetic efficiency, however, decreases as plug count increases because a higher local (dis)charge rate in the active zone is required to achieve the same system-level (dis)charge rate when many plugs are employed. This decrease in energetic efficiency lowers the amount of effective energy and therefore increases the cost per unit energy. Plug count is one example of many factors that influence cost per unit energy. The proposed design and analysis process allows the designer to quantitatively identify such competing factors and to optimize desired outcomes.

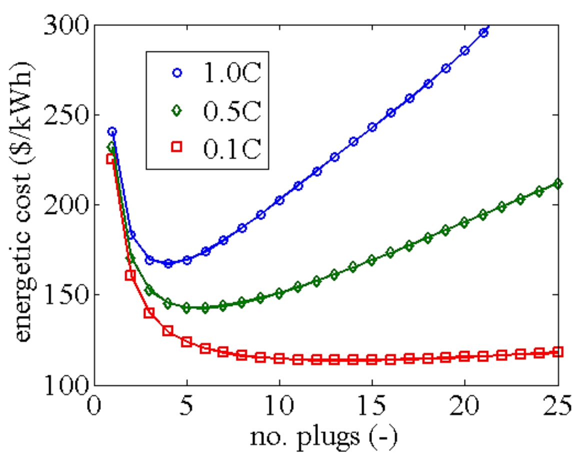

Fig. 1: Cost per unit of energy as a function of the number of plugs of a 1 kW battery for a range of system-level (dis)charge rates. C is the rate concomitant with full (dis)charge in 1 hour.

References

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