Performance of a Regenerative Fuel Cell System for the Lunar Surface

National Aeronautics and Space Administration

Background

Regenerative fuel cells (RFCs) are an attractive energy storage solution for lunar missions as a technology capable of providing a higher specific energy (i.e., W·h/kg) than state-of-the-art packaged Li-ion battery systems. An RFC consists of the (1) fuel cell (i.e., chemical to electrical energy conversion device to supply electricity to an external load), (2) electrolyzer (i.e., electrical to chemical energy conversion device to dissociate water into hydrogen and oxygen gases with supplied electrical power), (3) fluidic conditioning, (4) reactant storage, (5) avionics, (6) power management and distribution (PMAD), and (7) thermal management, as seen in Figure 1.

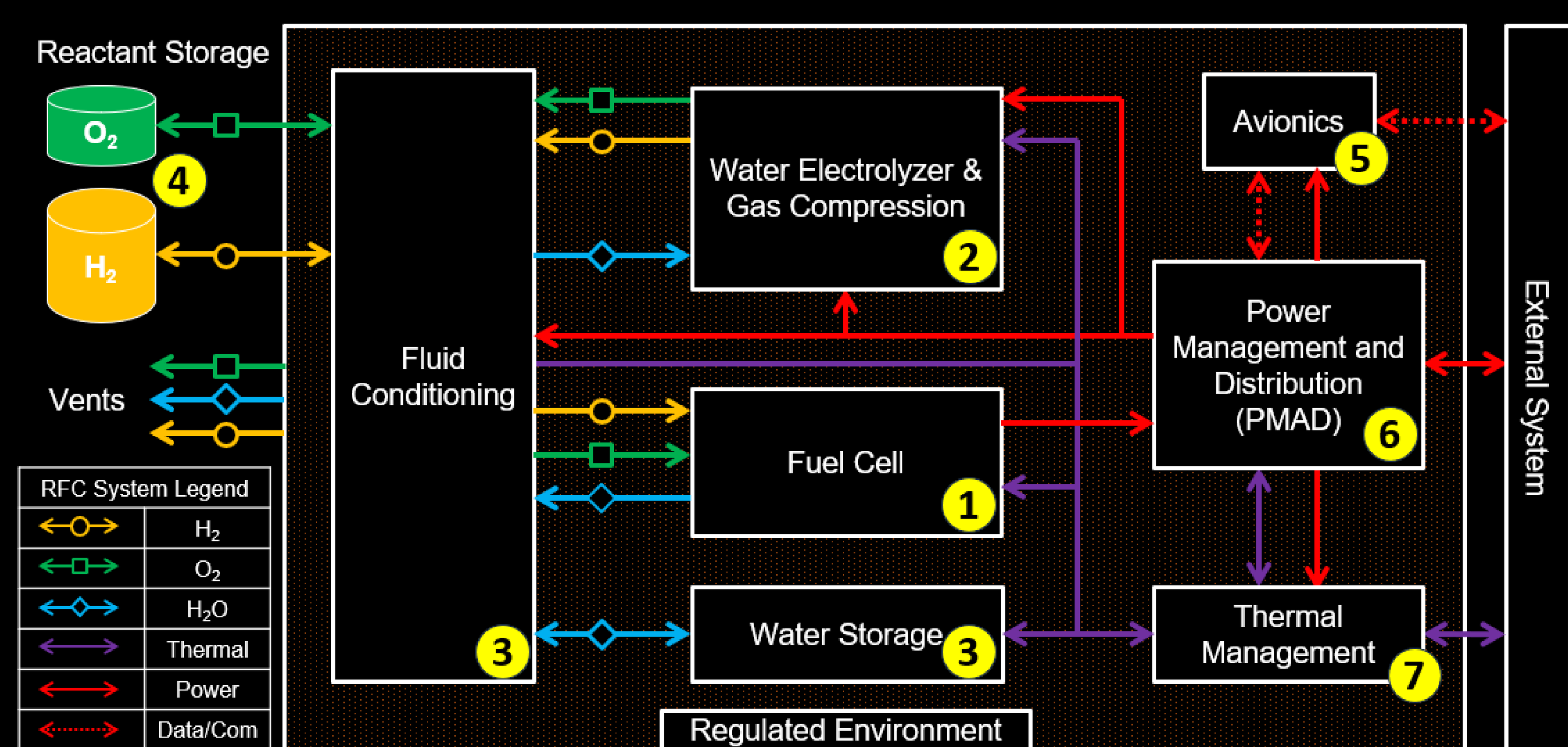
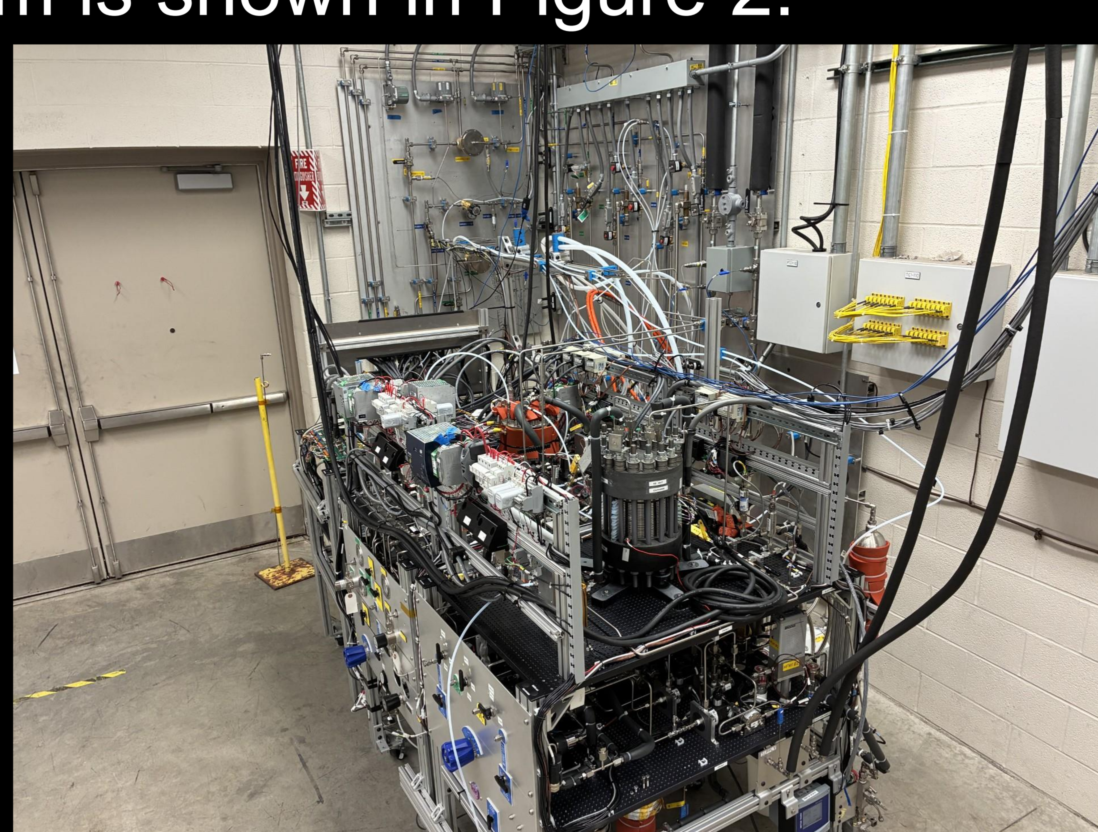


Figure 1. Functional block diagram of a regenerative fuel cell system.

Regenerative Fuel Cell System

The breadboard RFC system, assembled at NASA Glenn Research Center, is comprised of a non-flow through proton exchange membrane (PEM) fuel cell (FC) stack and a liquid-anode feed PEM electrolyzer (EZ) stack designed to electrochemically compress the reactants at balanced pressures up to 12.4 MPa (1800 psia). The fluidic conditioning, avionics, PMAD, and thermal management subsystems are largely comprised of commercial-off-the-shelf components for this system-level development effort. The hardware is controlled by a CubeSat space processor running an operational program based on core flight architecture that can control the RFC hardware autonomously through a state machine with fault monitoring. The RFC system is shown in Figure 2.

Figure 2. Breadboard RFC system integrated for testing.



Testing and Results

Testing was completed with the system in an open-loop configuration such that reactants generated through EZ operation were vented while gas cylinders supplied FC operation. The charge and discharge power and an estimated state of charge over three simulated lunar day/night cycles can be seen in Figure 3. The breadboard operated autonomously, but there were five unplanned transitions to a safe state that required a manual restart after reviewing the data, determining a root cause, and implementing a solution. Four of the transitions were caused by the thermal management subsystem and the fifth was caused by a water management control issue in the EZ subsystem. The RFC system operated for over 550 hours with the final cycle being slightly abbreviated due to reasons unrelated to system performance.

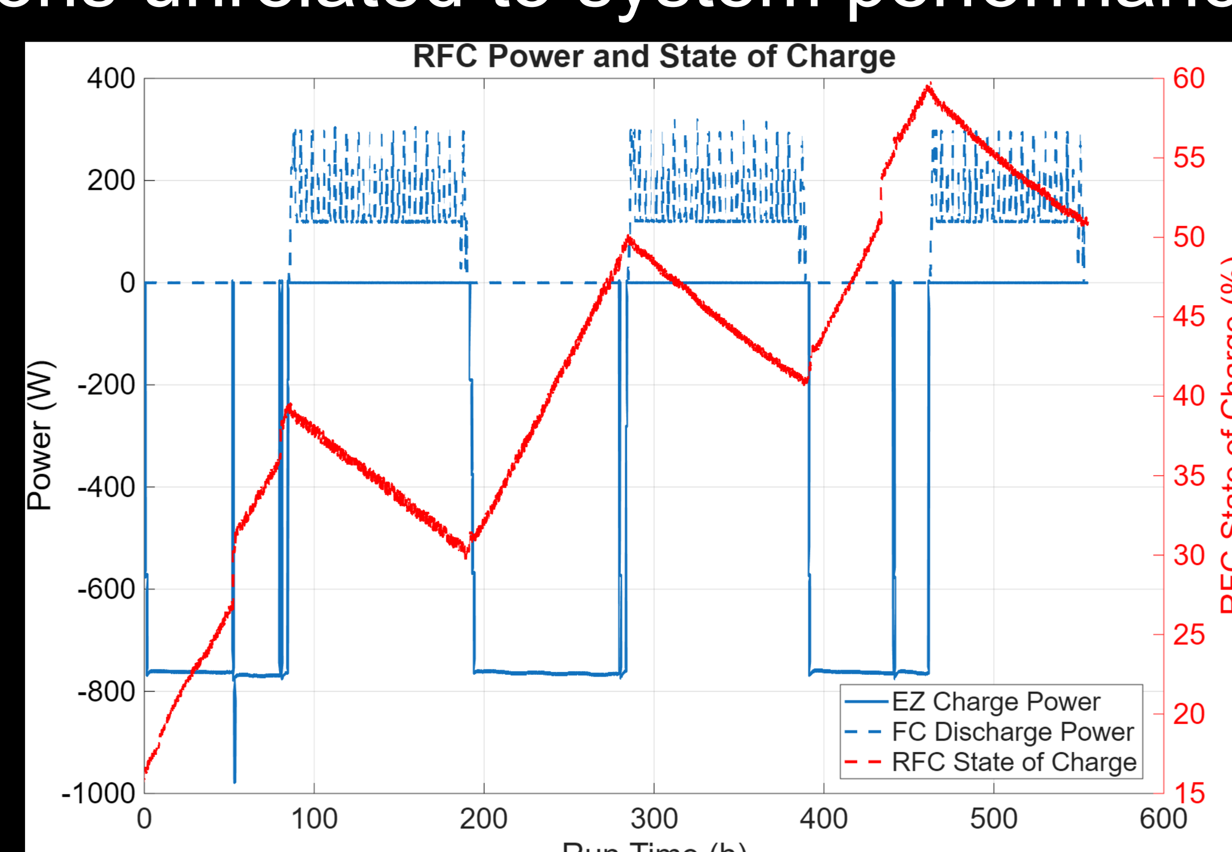


Figure 3. RFC charge and discharge power and estimated state of charge for the breadboard RFC system over 3 simulated lunar day/night cycles.

Future Work

Additional development and environmental testing to demonstrate the system to technology readiness level (TRL) 6.

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