REGENERATIVE FUEL CELL-BASED ENERGY STORAGE SYSTEMS FOR LUNAR SURFACE EXPLORATION. Monica C. Guzik[1], Ryan P. Gilligan[1], Phillip J. Smith[1], and Ian J. Jakupca[1], [1]NASA John H. Glenn Research Center, Cleveland, OH, 44011, United States

Abstract: The National Aeronautics and Space Administration (NASA) continues to develop technologies to satisfy the persistent need for consistent and reliable power systems that enable Lunar surface exploration. The traditional power architecture solution sizes a photovoltaic solar array to both power the customer load and charge an energy storage system while sunlight is available. When sunlight is unavailable during the lunar night, the energy storage system discharges to support the customer loads. In the past, batteries have met the energy storage needs over short charge/discharge durations with the lowest overall mass and fewest system complications compared to other technologies. However, the lengthy eclipse durations and challenging thermal environments inherent in many lunar surface exploration locations result in longer discharge periods with higher energy storage requirements to survive the cold temperatures during the lunar night. For such missions, the battery mass quickly becomes prohibitively large, necessitating an alternative energy storage method. One such alternative is the Regenerative Fuel Cell (RFC).

A Proton Exchange Membrane (PEM)-based RFC system integrates a fuel cell, an electrolyzer, and a multi-fluid reactant storage system into an energy storage device. The energy capacity of the RFC is determined by the amount of available hydrogen and oxygen storage. Typically, hydrogen and oxygen are stored as gases at elevated pressure, due to the advantage of decreased system volume and simplified thermal requirements. Previous system trades suggest that the optimum gaseous storage pressure is in the range of 1000 to 1800 psia, but may vary based on the mission requirements, particularly when overall volume minimization is required in addition to system efficiency.

The RFC discharges power through a fuel cell that converts the stored chemical energy of oxygen and hydrogen into direct-current electricity, heat, and water. This product water is accumulated until it is later consumed in the charging portion of the cycle. Fuel cells are, inherently, a current-producing device with the resulting electrical potential (voltage) indicating the reaction efficiency. Increasing the system pressure and temperature increase the reaction efficiency by increasing the molecular concentration and reaction kinetics. For PEM fuel cells, the standard operational regimes are 40 to 65 psia and 20 to 80°C.

Unlike RFC systems, batteries incorporate energy conversion (power) and energy capacity (storage) into one package that encompasses both the energy storage mass and the power production mass. An RFC dissociates the two masses, thereby enabling independent sizing of each. Because an RFC stores chemical energy as gases, it is able to store energy in large quantities with a relatively low mass penalty. This advantage becomes more pronounced as energy storage levels increase. NASA continues to evaluate RFC systems for lunar surface exploration, inclusive of lunar night survival and operations, as the sub-systems and individual technology elements mature.

This presentation highlights the updated results of a recent NASA study funded under the Advanced Exploration Systems (AES) Modular Power Systems (AMPS) project using an analysis method previously developed under the AMPS project. Both manned and robotic exploration of the lunar surface will require optimized energy storage solutions that minimize system mass and volume, while maintaining the capability to provide power and heat to survive the lunar night. Each mission has a unique set of requirements based on its location and application that may result in different technology solutions. Performing high-level analysis of the available energy storage options may allow mission designers to converge on a technology solution early in the architecture definition process, allowing for more effective optimization of the final system design. Using the data presented, high-level system sizing of an RFC energy storage system for a given lunar mission can be performed to aid in architecture trade studies. Following the selection of an RFC system as a viable solution for a given mission, the detailed models used to generate the presented data can be used for system optimization and further efficiency gains.