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IAF SPACE POWER SYMPOSIUM (C3)
Space Power System for Ambitious Missions (4)

Author: Mr. Gianluca Filippi
University of Strathclyde, United Kingdom, g.filippi@strath.ac.uk

Mr. Drew Gillespie
University of Strathclyde / Mechanical and Aerospace Engineering, United Kingdom, drew.gillespie@me.com
Dr. Andrew Ross Wilson
University of Strathclyde, United Kingdom, andrew.r.wilson@strath.ac.uk
Prof. Massimiliano Vasile
University of Strathclyde, United Kingdom, massimiliano.vasile@strath.ac.uk

# A RESILIENCE ENGINEERING APPROACH TO THE DESIGN OF FUTURE MOON BASE POWER SYSTEMS

**Abstract**

This paper proposes a novel approach to the design of complex engineering systems which maximise performance, and global system resilience. The approach is applied to the system level design of the power system for future Moon bases.

The power system is modelled as a network, where each node represents a specific power unit: energy storage, power distribution, power generation, power regulation. The performance and resilience of each power unit is defined by a mathematical model that depends on a set of design (control) and uncertain variables. The interrelationship among nodes is defined by functional links. The combination of multiple interconnected nodes defines the performance and resilience of the whole system.

An optimisation procedure is then used to find the optimal values of the design parameters. The optimal solution maximises global system resilience where an optimal resilient solution is either robust, i.e. it is not subject to disruptive failures, or recovers from failures to achieve a functioning state, albeit different from the starting one, after a contingency occurs.

The power system supports a Lunar base developed within the ESA-lab initiative, IGLUNA, led by the Swiss Space Centre. The power system, developed at the University of Strathclyde as part of the PowerHab project, is composed of nine interconnected elements: a hydrogen fuel cell energy storage system, a thermal mass storage system, a lithium-ion battery storage system, a constellation of solar power satellites (SPS) working in conjunction with a microwave wireless power transmission system, a reflecting satellite constellation and a ground-based solar power array. Distinct space and ground segments are identifiable, with orbit, AOCS and reflecting satellite nodes cooperating to provide optimal performance of the SPS constellation. The ground segment encompasses the ground-based solar array, energy storage systems, Lunar habitation module and the power transmission lines connecting these elements. Power generation is predominantly supplied by the ground-based array, with the SPS constellation and energy storage systems complementing this source; as well as providing redundancy and a reliable power supply during the Lunar night period.