LUNAR POWER GRID: DYNAMIC MODELING OF GRID SYNCHRONIZATION USING 3 kV AC AND 1000 Hz USING ONLY SOLAR POWER GENERATION

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Introduction: NASA intends to "develop an incremental Lunar power generation and distribution system" [1] to support a continuous human presence and robust Lunar economy. Thomas [2] provides an Artemis Grid Trade study which concluded that 3 kV AC is the mass-optimal feasible design solution, since any DC system was practically limited to 1.2-1.5 kV due to the lack of high voltage radiation-hardened switches. Walth [3] reviewed the stability of a proposed 3 kV 1000 Hz AC Lunar microgrid using a dynamic model for synchronization assuming a central 40 kW Fission Surface Power (FSP) reactor, concluding a system with robust grid coupling moves toward frequency synchronization.

FSP, however, may not arrive until the early 2030s [4] leaving solar as the most likely source of Lunar power generation through the end of the decade. Due to Lunar South Pole (LSP) topography, large and frequent variations in power generation should be expected with the "maximum power attainable varying by up to a factor of two through a Lunar day" [5]. These variations in generation present critical challenges to grid stability which need to be accounted for.

Study: This study investigates the stability of a 3 kV AC 1000 Hz Lunar microgrid, using only solar power generation. In the absence of FSP to provide inertia to the grid [3], disturbances may lead to larger amplitude deviations from the desired synchronization frequency. Upon a solar shading event, the deviation is characterized by magnitude, frequency, and temporal shift. These effects are then analyzed in the context of electrical equipment resilience. The results of this analysis will be published at the Space Resources Roundtable in June 2025.

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References:

[1] NASA (2022) *Moon to Mars Objectives.* [2] Thomas G. L. et al. (2023) Lunar Microgrid Trade Studies to Define Interface Converter Requirements. *ASCEND 2023*, 4784. [3] Walth M. et al. (2024) Lunar Power Grid: Network Structure and Spontaneous Synchronization. *arXiv preprint arXiv:2404.06374*. [4] Jones A. (2024) *Nuclear power on the moon: NASA wraps up 1st phase of ambitious reactor project.* [5] Ross A. K. et al. (2023) Preliminary quantification of the available solar power near the Lunar South Pole. *Acta Astronautica, volume 211*, 616-630.