LUNAR POWER GRID: Dynamic Modeling of Grid Synchronization Stability using 3 kV AC & 1000 Hz with only Solar Power Generation

K. Liang[1], M. S. Walth[2], P. Gläser[1], M. C. Tolton[1], [1]Orbital Mining Corporation (OMC), [2]Cornell University

Introduction

The first Lunar power grid involves architectural decisions, such as the selection of direct (DC) or alternating current (AC). While AC has a slight systems and mass edge over DC today, there are some potential AC issues which are not yet fully explored. So, the issue of **stability and inertia** are evaluated, in the context of a **solar-only Lunar grid.**

Background

A 2023 NASA trade study by Thomas et al. showed a slight mass saving and some key system reliability benefits by using a 3 kV AC and 1000 Hz grid architecture. With this architecture, a 2024 study by Walth et al. showed that a hub-and-spoke grid layout, centered on a Fission Surface Power (FSP) generator, will trend toward stability if a critical coupling value is exceeded.

This work extends the 2024 study to look at what happens when the FSP, which provides a high amount of stability "inertia," is replaced by only solar generation. This is the likely configuration of the first Lunar grid, and lack of inertia may cause significant issues with both grid stability and connected equipment.

Methods

We compared 2 dynamic models (Figure 1) of 10 generator/load nodes in a hub & spoke

Configuration:

- **A**: only solar generators (IBR)
- **B**: fission generator hub (2024 study)

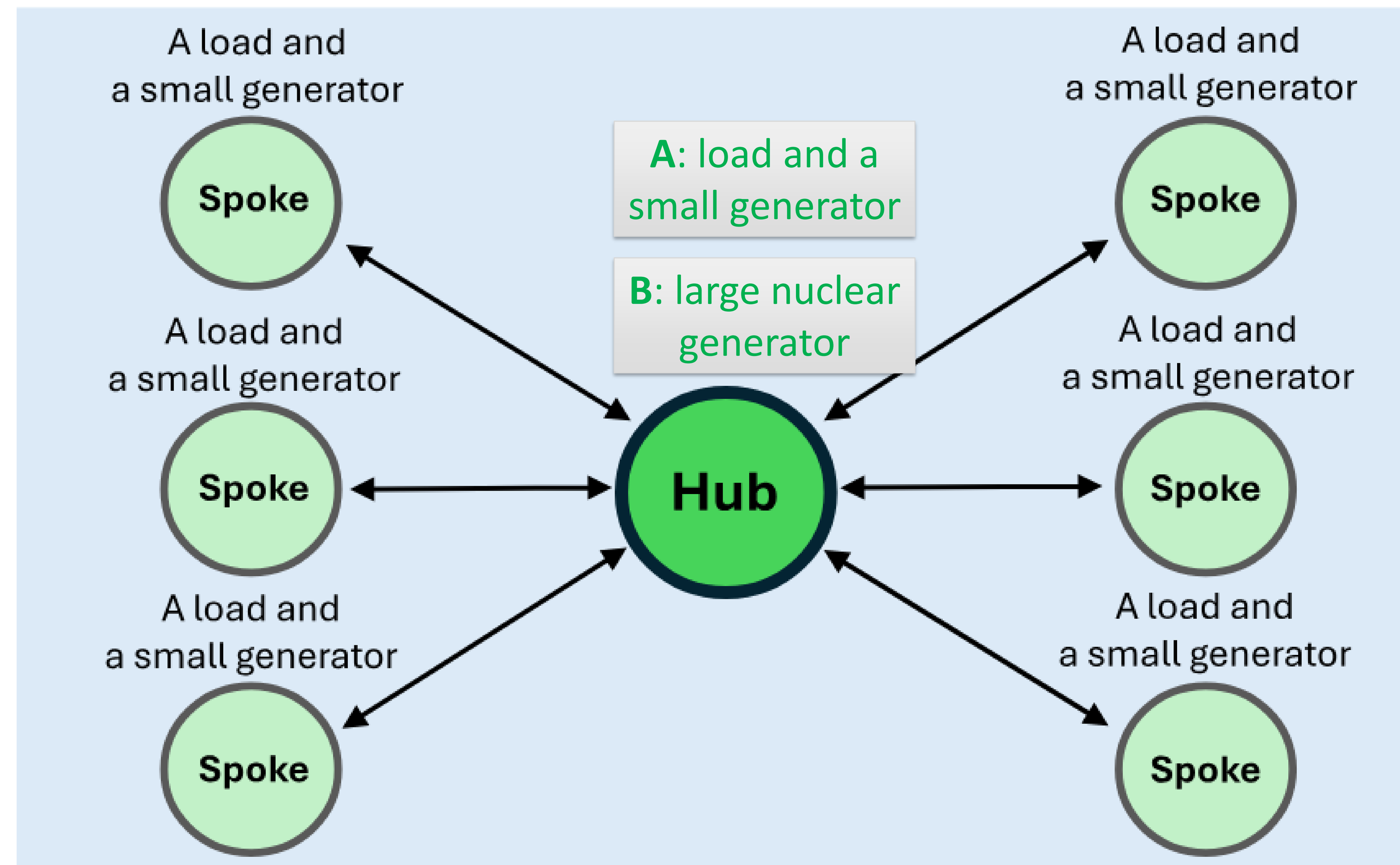

Figure 1: This network topology (Walth, 2024) was kept, with the large nuclear generator (configuration B) replaced by the "Spoke" node in configuration A

- 300 simulations were run for both models: a random disturbance was introduced, then frequency deviations were evaluated
- Deviation was measured using L^1 Loss of the integral of absolute frequency deviation (i.e., delta of time × frequency from ideal)

Results

In the rare unstable cases, the **all-solar** (IBR) model stabilized **quicker** than the fission model but had **larger deviations** from reference freq.

L^1 Loss after disturbance was between **30% to 400% worse** in the all-solar case vs. the fission-stabilized case

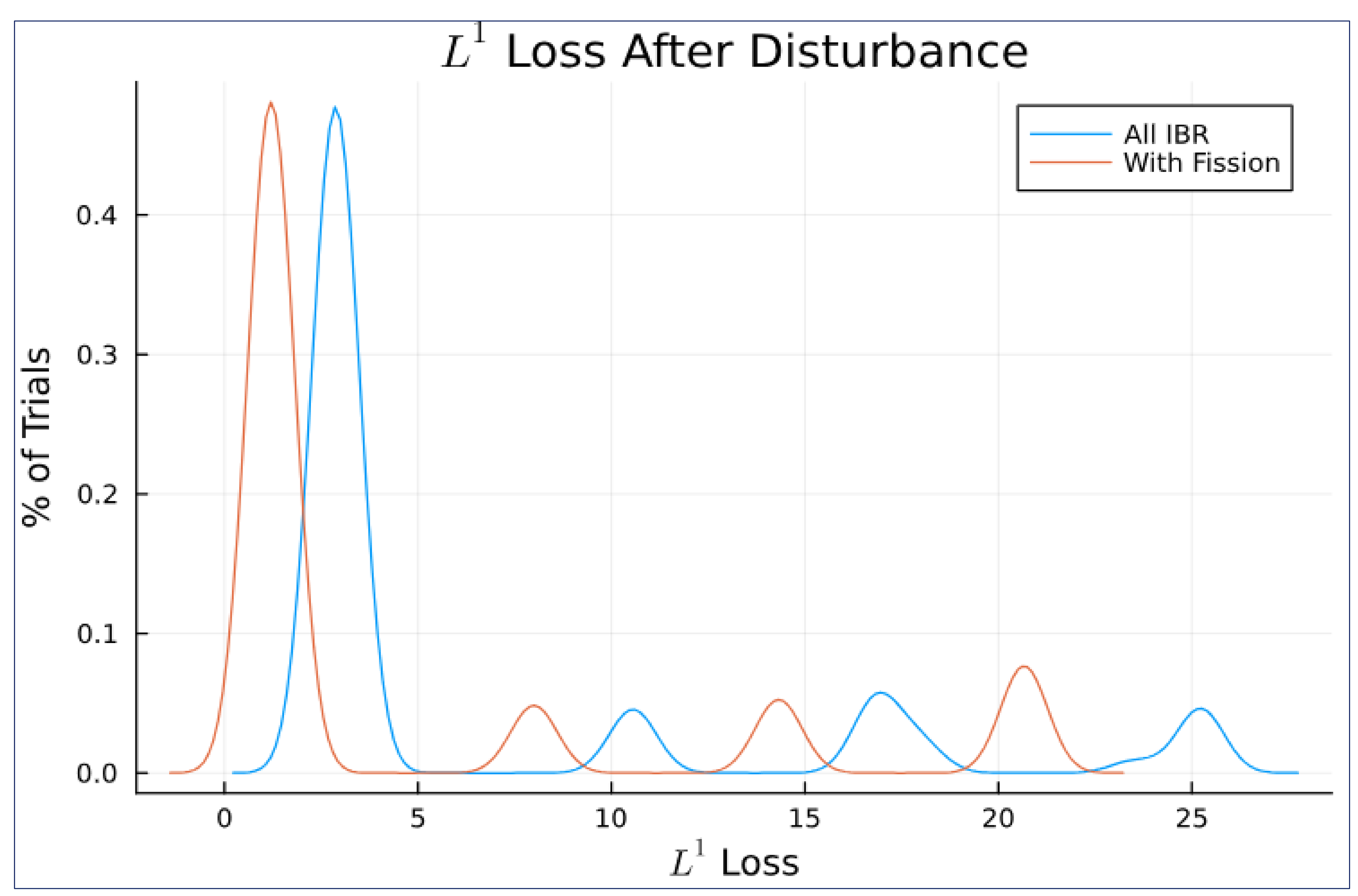

Figure 2: The L^1 Loss for [integral of time & frequency deviation] was compared between all-solar (blue) vs. a fission-anchored grid (red). All-solar trials tended to have worse instability.

Conclusion

In a hub and spoke network topology, using only solar generators in the Lunar grid will result in lower frequency stability, compared to the reference case of a grid anchored by a high-inertia nuclear fission generator.

This may present issues depending on the connected equipment's resilience to frequency deviation, network topology, or overall architecture.

Further Investigation

Further investigation topics:

- Novel blank-slate grid topologies and architectures which can mitigate or obviate frequency deviation risks
- AC frequency desynchronization event likelihood based on solar node locations and associated insolation characteristics
- Effects of different magnitudes of frequency deviation on various electrical systems

Contact

This research was funded and conducted by Orbital Mining Corporation, based in Golden, CO

Contact: ken@orbitalminecorp.com