Power and Energy Management System For Lunar Grids

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Motivation/Challenges

Transmission: 1–10 kms supporting missions with distance of at least 1 km. Wired and Wireless



Environment: 100K to 400K temperature variation on lunar surface. Radiation exposure

Power: 100Ws – 40kWs of power for supporting rovers and microgrids

Image taken from: Microgrid for Lunar Surface Power
Id:20210011121

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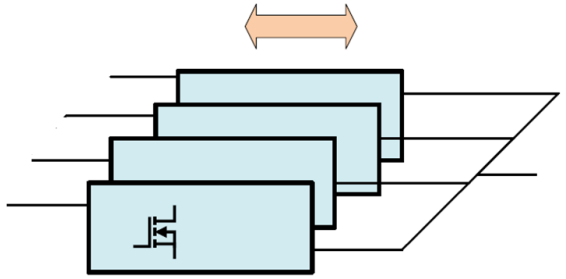
Power Distribution System

MODULAR SYSTEM



- Modular solution for interfacing energy storage
- AC or DC distribution system

WBG devices / module

GaN



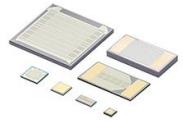


SiC

Improved materials



Nanocrystalline Core



Silicon Dielectric



Current SOA

- Si based
- Low frequency
- Low power density
  Slow response
- Limited scalability

Current trends

- WBG based (SiC, GaN)
- Ultra-high frequency
- High power density
  Modular, scalable and multiport

Goals

- Increase switching frequency – SiC & GaN
- Reduce voltage stress – GaN
- Advanced MW class magnetic components
- Reduce passive component size
- Novel architecture – improve power density
- Improve efficiency – less heat generation
- Divide total power – modular design

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How to Distribute Power?

Microgrid for Lunar Surface Power
Jeff Csank and James Soeder
March 2021

- Power needs
  - Mining and In-Situ Resource Utilization (ISRU)
  - Supporting crew and crew operation
  - Lunar science and technology demonstrations
- Power distribution
  - Power type (AC/DC) and voltage levels
  - Topology: Interconnected microgrids, centralized or distributed
  - Energy management system
  - Sizing of distributed power system resources (generation, storage and loads)



Image taken from: Microgrid for Lunar Surface Power
Id:20210011121

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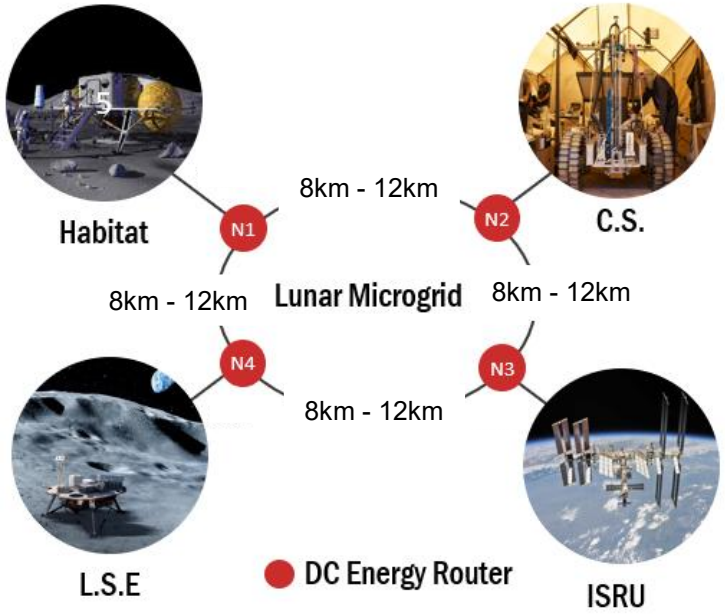
Interconnected Microgrids

- Long distance power distribution system with modular power electronics
- Multiport converters/inverters that can easily be plugged into the distribution system.
- Smart energy management for a wide range of lunar microgrids



Charging station

Lunar science experiments

In-Situ-Resource-Utilization

Power and Energy for the Lunar, Jeffrey Csank, *John H. Scott* ARPA-e Tech to Market Briefing. 29th April 2022

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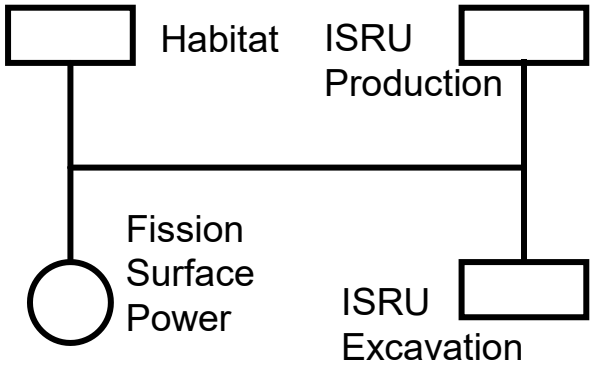
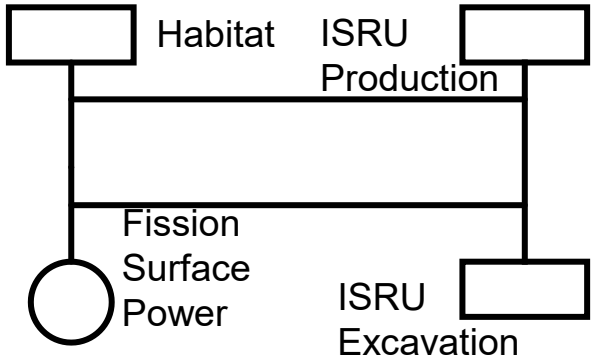
System Architectures

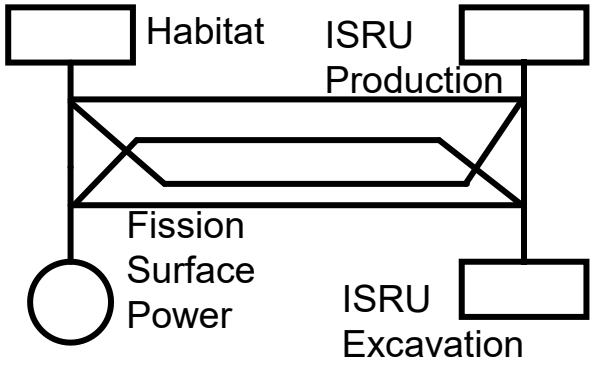
Radial



Ring



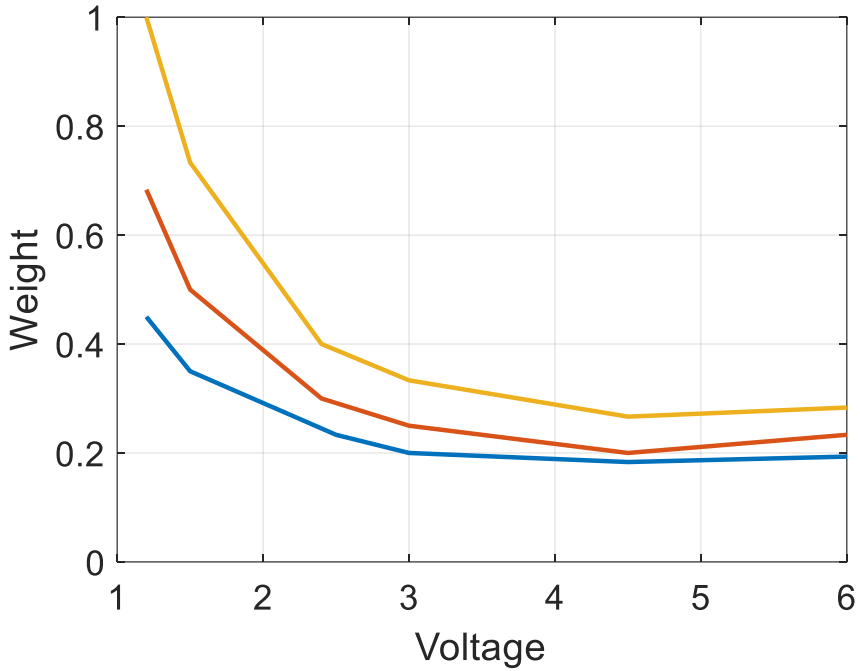
Mesh



<u>Radial</u>
- Simple, low cost and light weight
- Lack protection/redundancy during failure

<u>Ring</u>
- More line for efficient power transfer
- Heavier than radial

<u>Mesh</u>
- Dual line fault tolerance
- Heaver than the Ring



Weight decreases with the voltage

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Energy Management System (EMS)

- EMS responds to unanticipated deviations from the plan

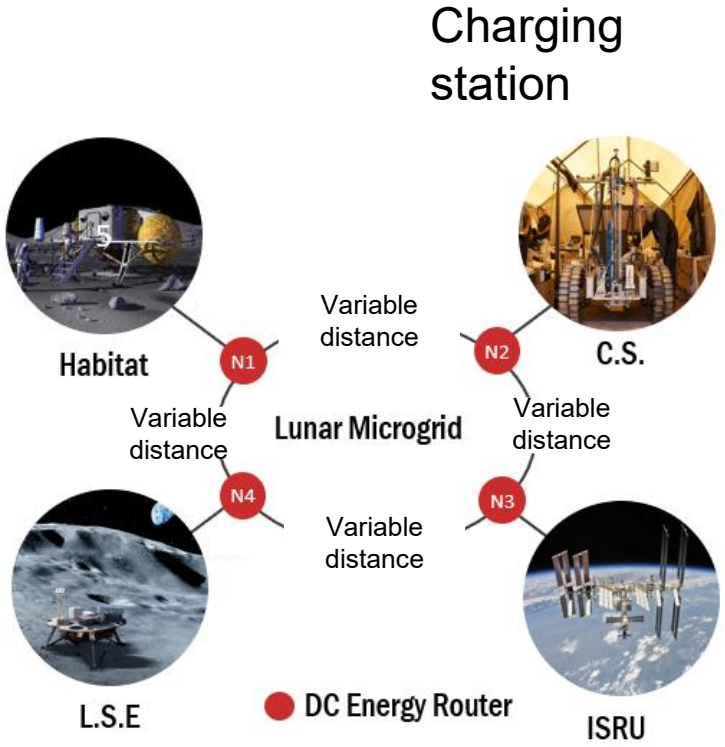
Objective Function

Min. $\sum_{t=1}^{T}(f(P) + f(\eta) + f(P_{shed}))$

Cost of dispatching energy source

Power conversion losses

Cost of load shedding



Lunar science experiments

In-Situ-Resource-Utilization

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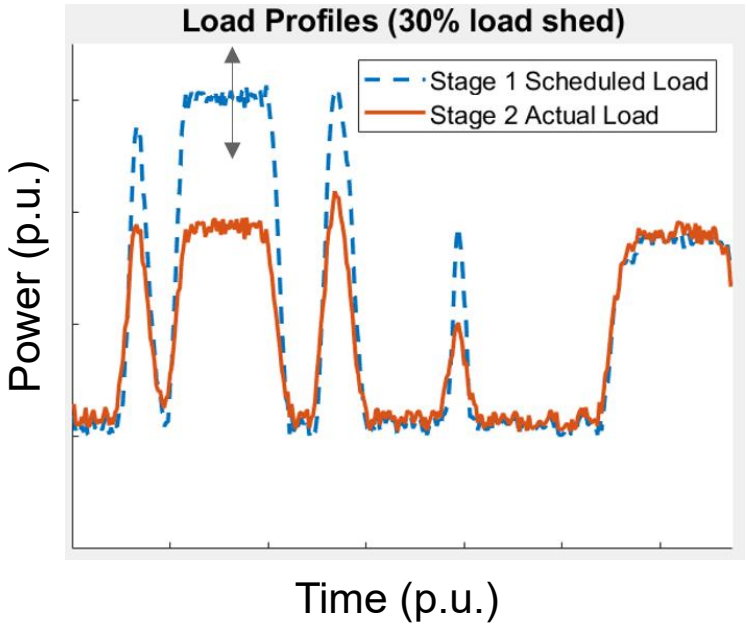
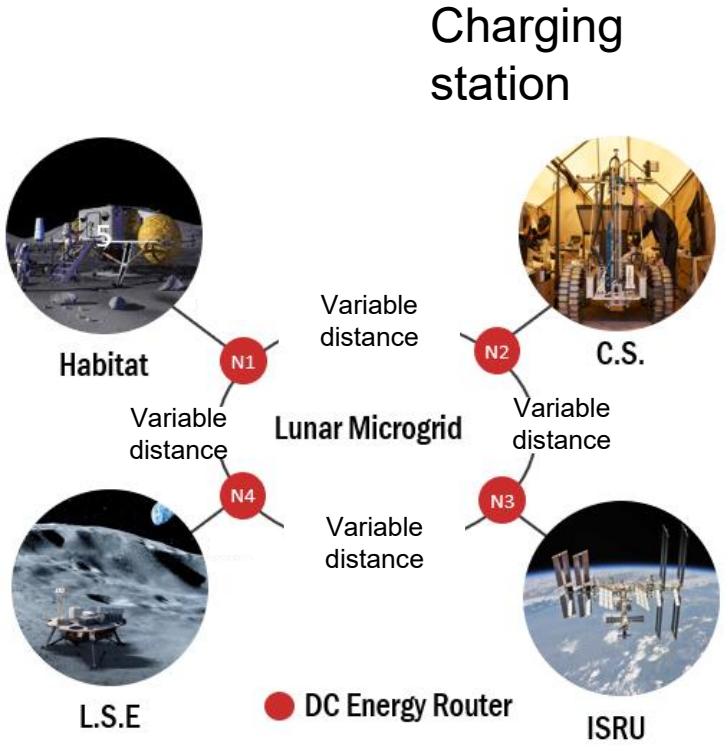
EMS: Load Planning

- Optimal set-points based on loads and solar forecast, and equipment status
- Repeated solution of finite-horizon stochastic programming problems

Load Shed





Lunar science experiments

In-Situ-Resource-Utilization

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Thank you

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