Tethered Power Systems for Lunar Mobility and Power Transmission (TYMPO)

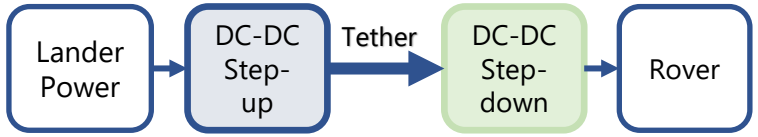
Berkeley Power and Energy Center

Motivation and Application

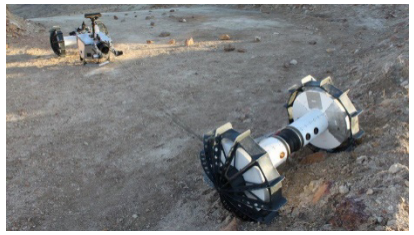
Extreme terrain capable robots will enable further exploration on sites such as pits on the moon and Martian landscape. Tethered power systems have been proposed to power these small rovers; however, they require high voltage DC power [1].

Challenges

High voltage switches are difficult to use in space due to radiation effects. Additionally, the high voltage conversion ratio makes it difficult to design a compact and efficient power converter. Therefore, multilevel topologies offer promising solutions [2].



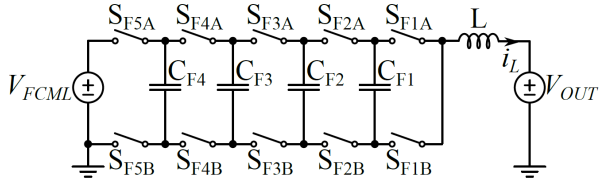
TYPMO architecture



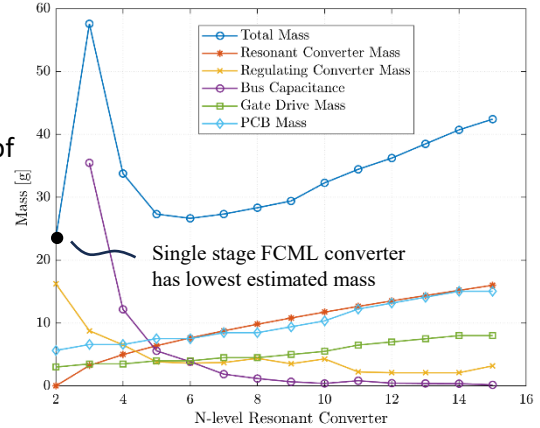
Tethered rover to explore lunar pits

System Architecture (Flying Capacitor Multilevel Converter)

- Comparison of cascaded structure consisting of resonant flying capacitor multilevel converter (FCML) and regulating FCML (resonant FCML + regulating FCML) vs single-stage FCML converter
- Bus capacitance requirement diminishes benefits of cascaded structure



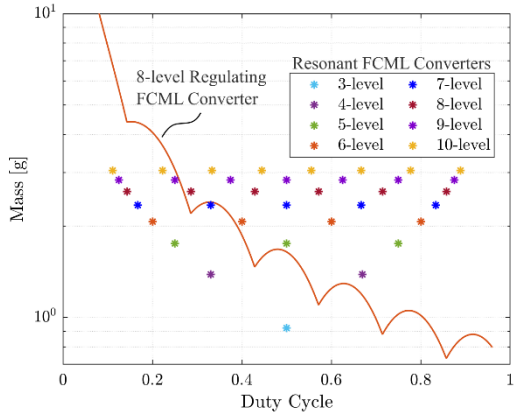
FCML converter schematic



Estimated mass breakdown of cascaded FCML converter structure

Passive Mass Minimization

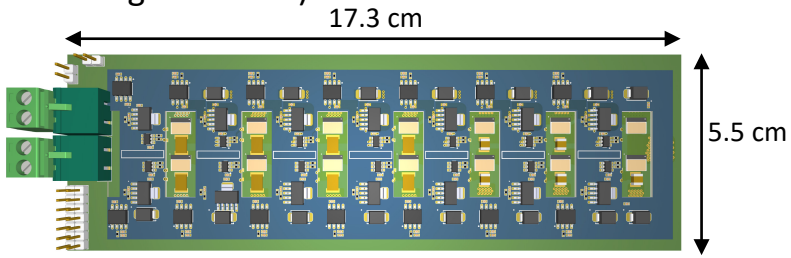
- Comparison of 8-level regulating mode FCML converter with a resonant mode FCML converter, demonstrating the advantages of a resonant converter in terms of passive component mass
- Each converter operating point is optimized for minimal mass based on the peak energy storage requirements of the passive components

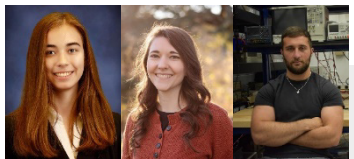


Hardware Verification

840 V-to-120 V space-rated FCML converter to verify:

- PCB structure (Gate drive daughterboard)
- Part selection
- Thermal solutions
- Mass optimization





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References:
[1] P. McGarey, W. Reid and I. Nesnas, "Towards Articulated Mobility and Efficient Docking for the DuAxel Tethered Robot System," *2019 IEEE Aerospace Conference*, 2019, pp. 1-9.
[2] P. McGarey, T. Nguyen, T. Pailevanian and I. Nensas, "Design and Test of an Electromechanical Rover Tether for the Exploration of Vertical Lunar Pits," *2020 IEEE Aerospace Conference*, 2020, pp. 1-10.
[3] S. Coday, A. Barchowsky and R. C. N. Pilawa-Podgurski, "A 10-level GaN-based Flying Capacitor Multilevel Boost Converter for Radiation-Hardened Operation in Space Applications," *2021 IEEE Applied Power Electronics Conference and Exposition (APEC)*, 2021, pp. 2798-2803.