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Development of Hierarchical Control for a Lunar Habitat DC Microgrid Model Using Power Hardware-in-the-Loop

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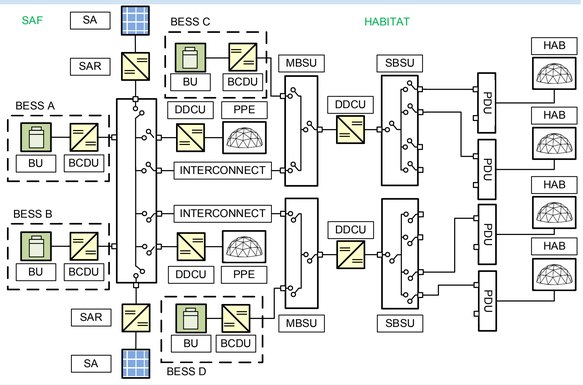
Introduction

A hierarchical control for a lunar habitat DC microgrid is implemented in a real-time simulation model. The control scheme and real-time simulation model are tested on a hardware DC/DC converter using a Power Hardware-in-the-Loop (PHIL) platform.

Experimental results demonstrate the dynamic performance of the DC/DC converter operating under a hierarchical control scheme. The real-time simulation model and PHIL platform are subjected to varying environmental conditions to best characterize system performance.

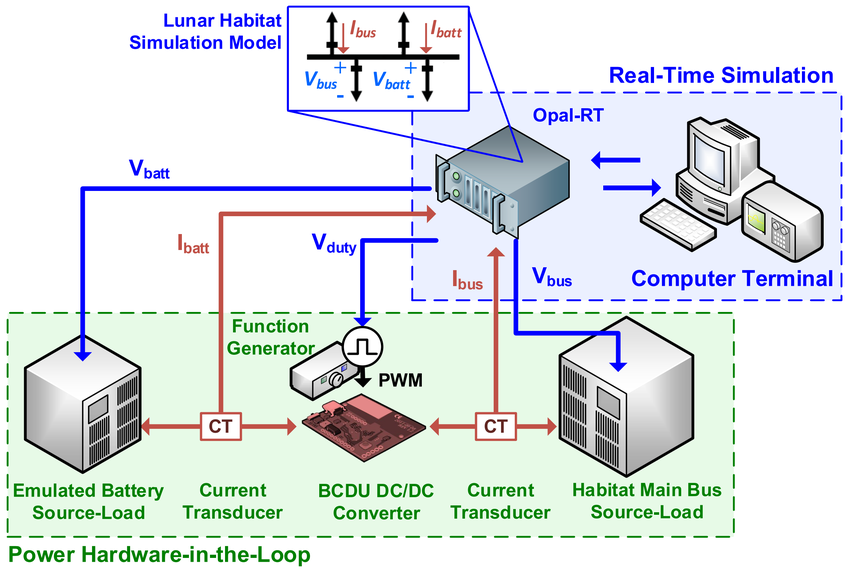
Lunar Habitat Microgrid Model

- PV Arrays and Solar Array Regulators (SAR)
  - MPPT-based SEPIC
- Battery Energy Storage Systems (BESS)
  - Lithium-ion Battery Units (BU)
  - Bidirectional DC/DC Converters (BCDU)
- Habitat Loads on Main Bus
  - Buck DC/DC converters (DDCU)



Power Hardware-in-the-Loop (PHIL)

PHIL platform developed to test DC power hardware for the lunar habitat application. A real-time simulation controls DC source-loads and the BCDU DC/DC converter in a microgrid test environment.



Experimental Test Results

- Hardware converter for BESS (in red) tested alongside real-time simulation models.
  - First half of simulation in peak irradiance.
  - Second half of simulation in eclipse.
- Hierarchical control adjusts hardware BCDU current set point to preserve state-of-charge (SoC), adjustments shown at 50%.

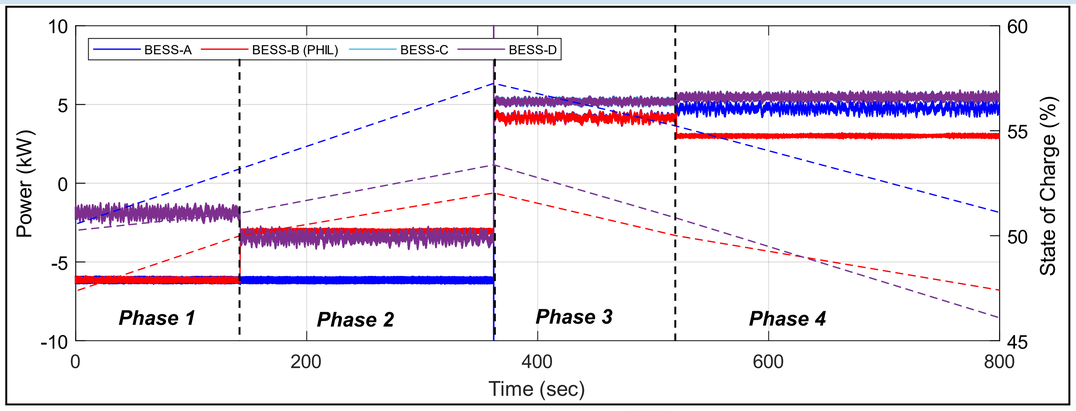
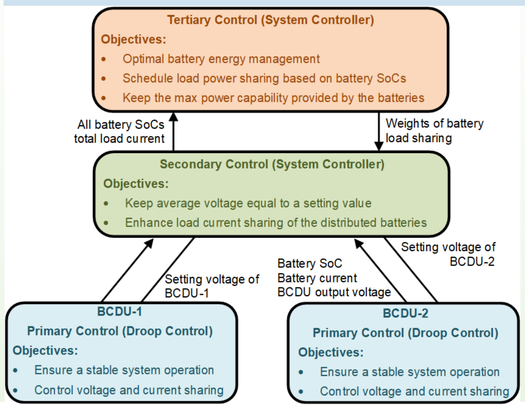


TABLE I:
AVERAGE POWER CONTRIBUTIONS DURING RUN-TIME

	Full Irradiance / BESS Charge (W)		*Eclipse / BESS Discharge (W)*	
Power Source/Load	***Phase 1 0-120s***	***Phase 2 120-240s***	***Phase 3 240-360s***	***Phase 4 360-480s***
SA	37278	37296	0	0
BESS A	-6149	-6157	4175	4757
BESS B (PHIL)	-6141	-3052	4168	3005
BESS C	-1894	-3456	5184	5472
BESS D	-1894	-3456	5184	5472
Load	18686	18686	18533	18522

Hierarchical Control Method



Hierarchical control manages battery SoC via BCDU:

- **Tertiary Control:** Battery SoC is passed into system controller to determine BCDU control set points.
- **Secondary Control:** Droop controller's current set point determines average duty cycle value of the converter.
- **Primary Control:** Average duty cycle value sets PWM waveform to converter for power transfer.

Conclusions

- ***PHIL platform successfully integrates power hardware into lunar habitat DC microgrid development.***
- ***Performance of controlled hardware BCDU equivalent to real-time simulation models. Hierarchical control provides additional functionality for preserving SoC over time and varying environmental conditions.***
- ***Hierarchical control methods can be further developed in DC PHIL platform to expand the lunar habitat microgrid model's capability.***

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