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Evaluation of Optimal Net Load Management in Microgrids Using Hardware-in-the-Loop Simulation

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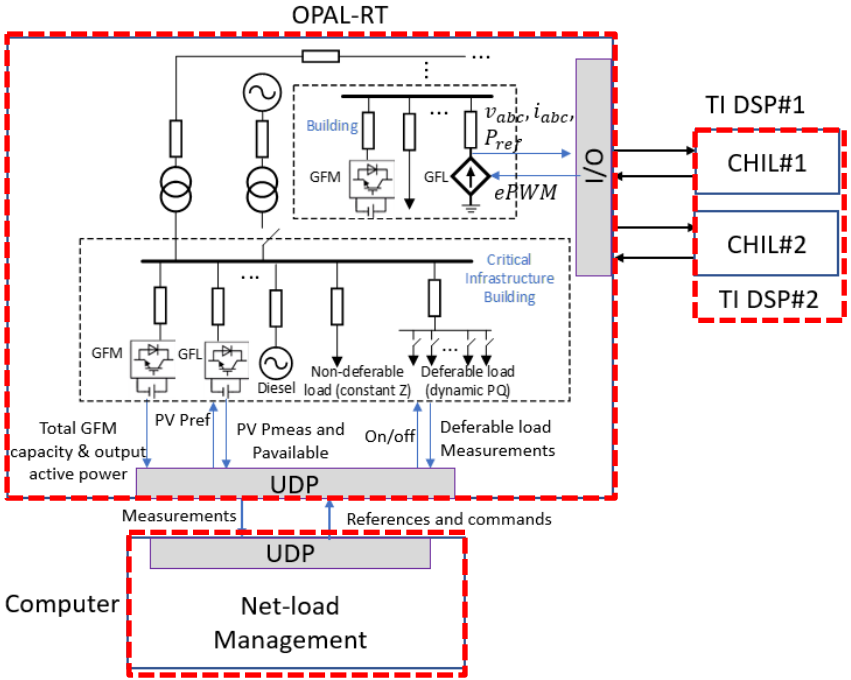
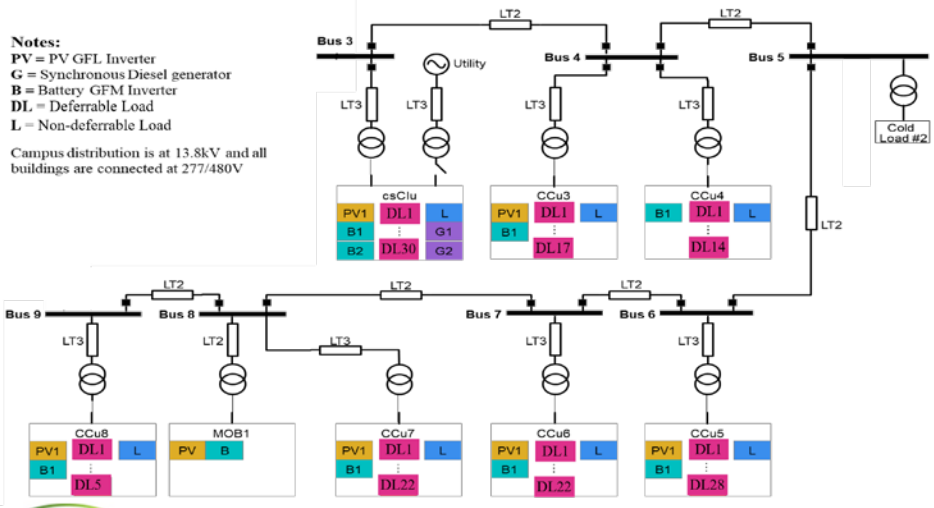
HIL Evaluation Overview

- Objective: Validate the net load management (NLM) algorithm against a simulated real-world campus microgrid in a realistic testing environment.
  - Accurate modeling of a campus microgrid, including grid-forming (GFM) battery inverters, grid-following (GFL) photovoltaic (PV) inverters, transformers, lines, and dynamic loads
  - Real-time implementation of NLM algorithm
  - Controller-hardware-in-the-loop (CHIL) testing of two GFL inverter control algorithms
  - The NLM controller interacts with the real-time simulation model as if the controller were interacting with a real-world system.

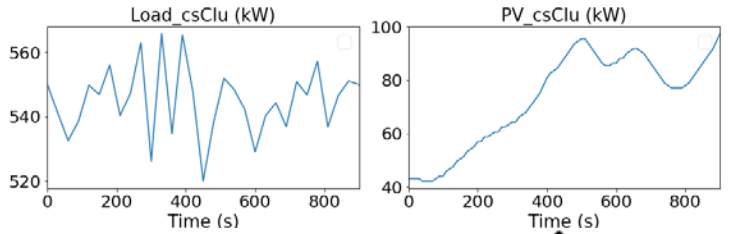


CHIL Implementation and Testing Conditions

- University of Minnesota campus microgrid:
  - Islanded mode and grid-forming by nine GFM battery inverters
  - Power sharing among GFM inverters
  - NLM optimal dispatch of GFL inverters and loads.

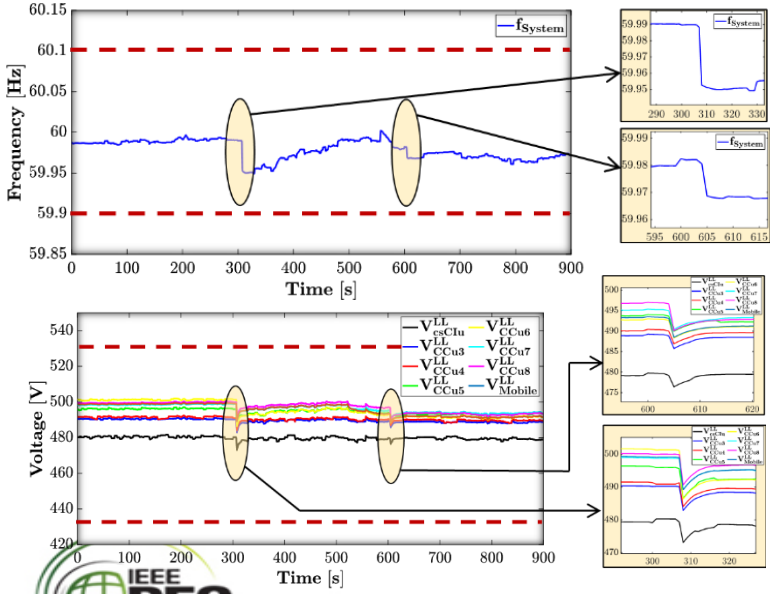


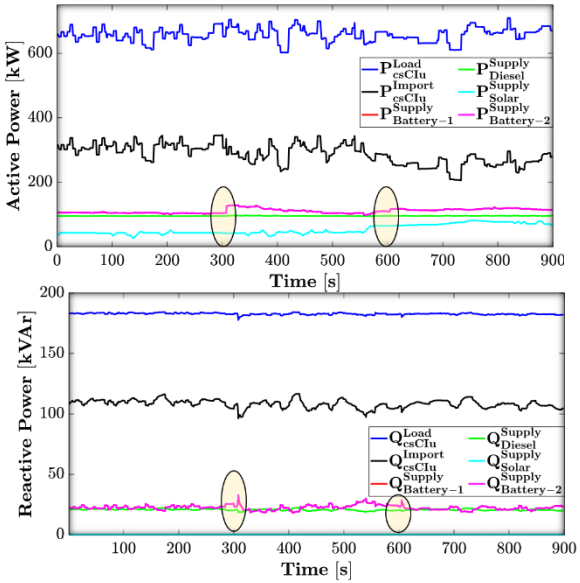
Net Load Type	Net Load Resource Power Capacity (kVA) **								
	csClu	CCu3	CCu4	CCu5	CCu 6	CCu7	CCu8	MOB1	Cold Load 2
PV1	100	50	-	100	100	50	100	50	-
B1	100	25	100	80	200	100	50	100	-
B2	100	-	-	-	-	-	-	-	-
G1/G2	50	-	-	-	-		-	-	-
L	250	30	35	30	40	25	30	-	200
DL	500	300	315	300	360	225	270	-	-

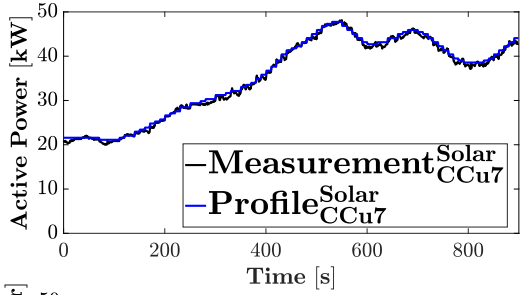


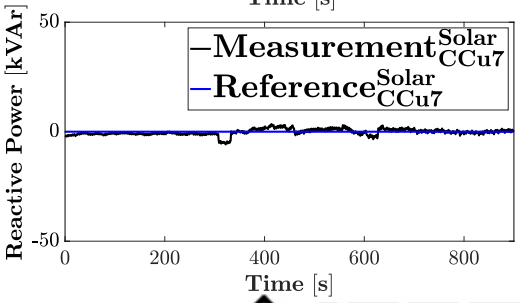
Experimental Results

- Goal: Serve at least 50% deferrable loads in csCIu and maintain system voltage and frequency within the target limits.
- Two contingency events: (1) lost 200-kVA battery inverter at CCu6 at 5 minutes and (2) lost 50-kVA battery inverter at CCu8 at 10 minutes.









Conclusions

- The performance of the NLM algorithm is effectively evaluated with the laboratory HIL simulation.
- The measured system frequency and voltages meet the metrics, and the droop control for power sharing and the NLM's balance of generation and load can achieve viable and stable operation of the microgrid.
- Future work should include secondary control to regulate the system voltage and frequency to nominal values and for better stability.

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