Use of Grid-Forming Medium-Voltage Power Electronics Hub in a Microgrid Setting

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BACKGROUND/INDUSTRY IMPACT

- Distribution power systems with microgrids face a variety of challenges related to feeder loading, reliability, efficiency, and power quality.
- This paper presents the development of advanced grid-support control algorithms and coordination strategies for integrating the multiport, modular, medium-voltage power electronics hub (M3PE-HUB).
- The proposed M3PEHUB offers several advantages including the integration of multiple energy sources and loads, and efficient power flow management.

PROJECT OVERVIEW/OBJECTIVES

- The objective of this project focuses on the design and development of advanced grid-support control algorithms and coordination strategies for integrating the M3PE-HUB into the distribution system.
- This paper aims to improve the understanding of the effectiveness and interconnection of the M3PE-HUB system, with an emphasis on system-level advanced controllers.

ARCHITECTURE AND IMPLEMENTATION

- The simplified overall circuit diagram of the M3PE-HUB architecture connected to the Banshee model Bus 23 is presented in Figure. 3.
- Three M3PE-HUBs are linked to the Banshee system where Hub 1 is connected to Bus 23 with extra battery source, Hub 2 connects Bus 204 and 203, and Hub 3 connects Bus 201 and 203.

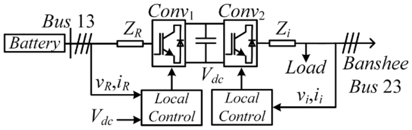

Figure. 1: Expanded view of the M3PE-HUB architecture

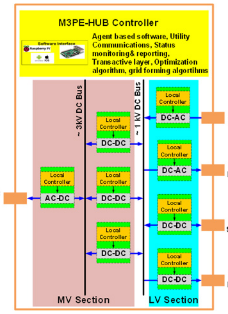

Figure. 2: M3PE-HUB control architecture

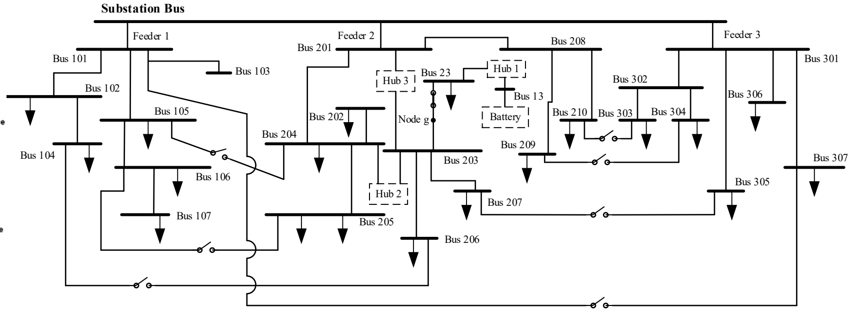

Figure. 3: Banshee microgrid model - one line diagram

SIMULATION RESULTS AND ANALYSIS

- Islanding Transition
  - This scenario uses a grid-forming (GFM) M3PE-HUB with dispatchable capabilities linked to Bus 23 with a controlled voltage source (external battery source) to deliver a 0.5MW load while the feeder supplies reactive power.
  - M3PE-HUB (HUB 1) switches to GFM mode and supplies reactive loads when the circuit breaker between Bus 203 and Bus 23 is open.
- Resynchronization Operations
  - When HUB 1 tries to close the breaker for Bus 23, internal control logics increase the voltage magnitude at Bus 23 and maintain the frequency at 60Hz. When phase angle difference at the both ends of the breaker lower than 5 deg, the breaker controller closes the breaker for Bus 23.
  - These results capture system transitions before and after the resynchronization which are crucial indicators of the system stability and adherence to grid requirements.

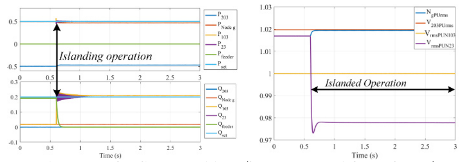

Figure. 4: Islanding Transitions (left: Powers; right: Voltages)

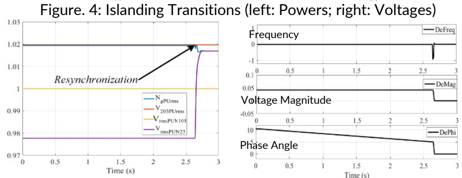

Figure. 5: Resynchronization Transitions (left: Voltage; right: Measurements)

- Multiple M3PE-HUBs for system reconfiguration
  - In this case, three M3PE-HUBs are linked to the Banshee system where Hub 1 is connected to Bus 23 with extra battery source, Hub 2 connects Bus 204 and 203, and Hub 3 connects Bus 201 and 203.
  - When M3PE-HUB 3 experiences a specific problem around 0.6 s, its protective system trips the device. Then, M3PE-HUB 1 and M3PE-HUB 2 quickly redistribute electricity to 0.47MW/0.27MW and 0.27MVar/0.27MVar.
  - These results demonstrate that multiple M3PE-HUBs can dynamically manage power flow with droop controls, and system voltage and frequency can reach stable operations.

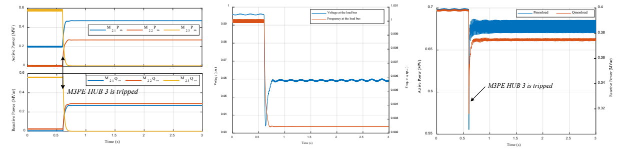

Figure. 6: M3PE-HUBs Transitions (left: Powers; middle: Voltage/Frequency; right: Active Loads)

METHODS

- The medium-voltage M3PE-HUB models are developed in a commercially available digital real-time simulator (DRTS).
- The Banshee microgrid is leveraged to act as test system for the evaluation M3PE-HUB's dynamic transit in feeder level and multiple grid-supporting functions.
- Systems are modeled in a commercially available DRTS platform (Real Time Digital Simulator (RTDS) is used in this work) in an electromagnetic transient (EMT) domain with a time step of 50 microseconds.

KEY OUTCOMES/MILESTONES

- Development of advanced grid-support control algorithms and coordination strategies for integrating the multiport, modular, medium-voltage power electronics hub (M3PE-HUB).
- Proof-of-concept and evaluation of M3PE-HUB based grid support functions at feeder-level.
- The power converter models, and test system are developed in a commercially available digital real-time simulator (DRTS), enabling future controller-hardware-in-the-loop (CHIL) tests with commercial SEL controllers.

SUMMARY

- This paper demonstrated the concept of the M3PE-HUB in a test microgrid system. The architecture of M3PE-HUB and a preliminary evaluation in DRTS were presented.
- The proposed M3PEHUB integrates numerous energy sources and loads and manages power flow efficiently, however its flexibility makes integration and scaling difficult.
- A follow-up work will continuedly explore use cases using the CHIL interface and go beyond the basic demonstration by presenting several additional corner cases to further emphasize the benefits and challenges of integration.

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