NREL efforts on Medium Voltage Converters and Controls enabling Grid Integration

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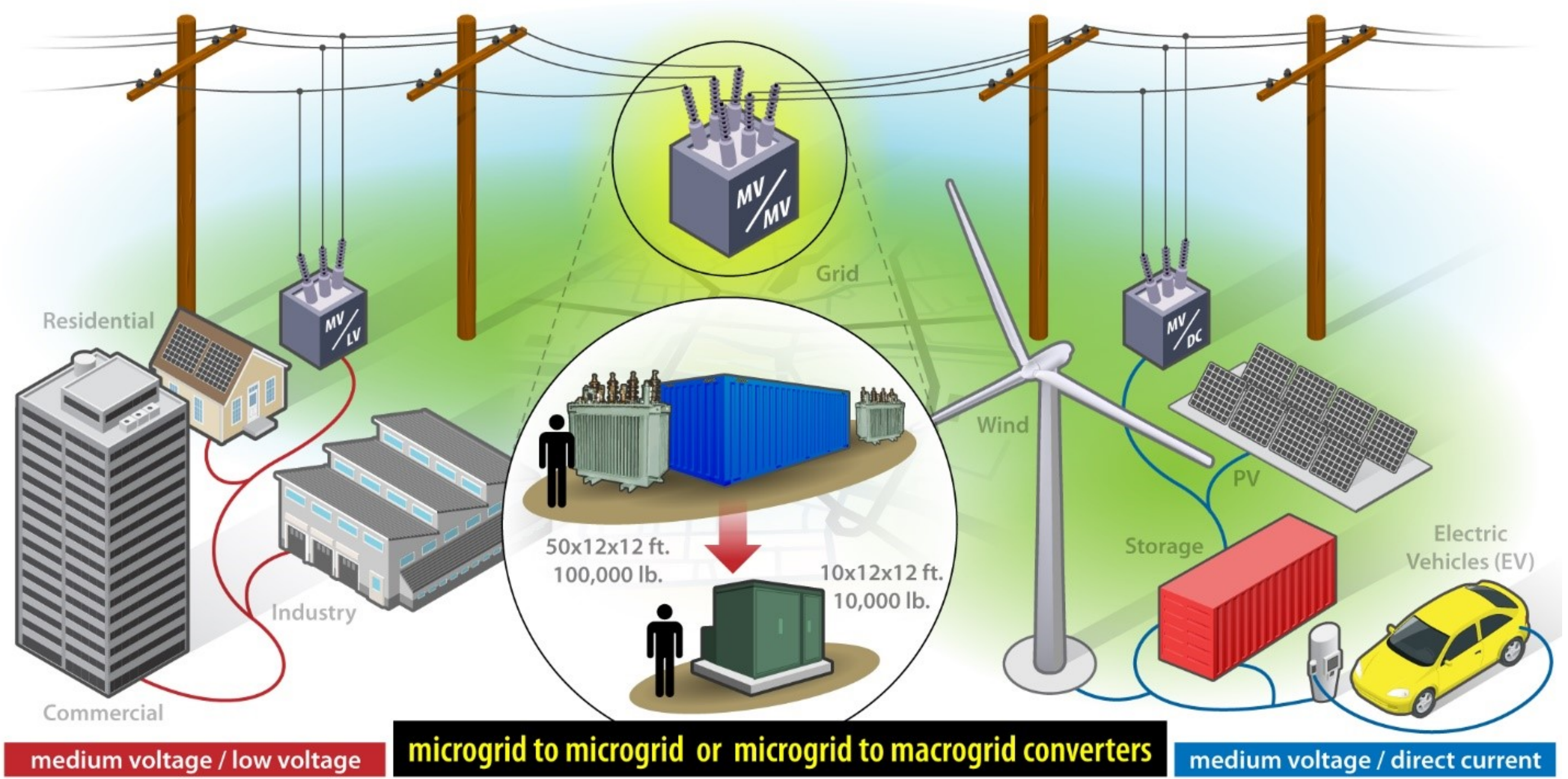
Outline

1. Background and Opportunity
2. Technical Innovation
3. Back-to-Back Converter Development
4. Advanced Grid Support Controls
5. Past MV projects
6. Existing and future capabilities
7. Conclusion

MV Converter Applications



Opportunity and Technical Innovation

- Back-to-back MV AC conversion today entails 60 Hz transformers down to 480-600 V_{ac} then power electronic conversion (system is heavy and expensive)
- Standards for "grid connectors" are not well defined
- Grid operation on radial feeders is limited, particularly in regions with high-levels of DERs, resulting in hesitation to install more DER and limited flexibility
- MV power electronics are difficult to test presently

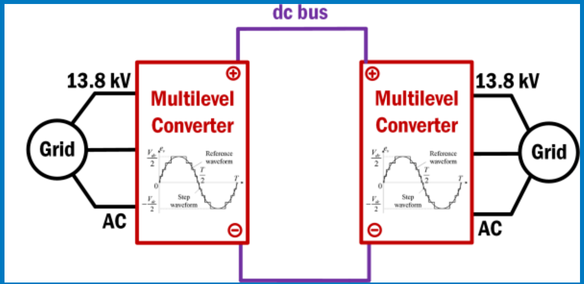
Grid Application Development, Testbed, and Analysis for MV SiC

NREL Transforming ENERGY

FLORIDA STATE UNIVERSITY 1851 VIRES ARTES MORES

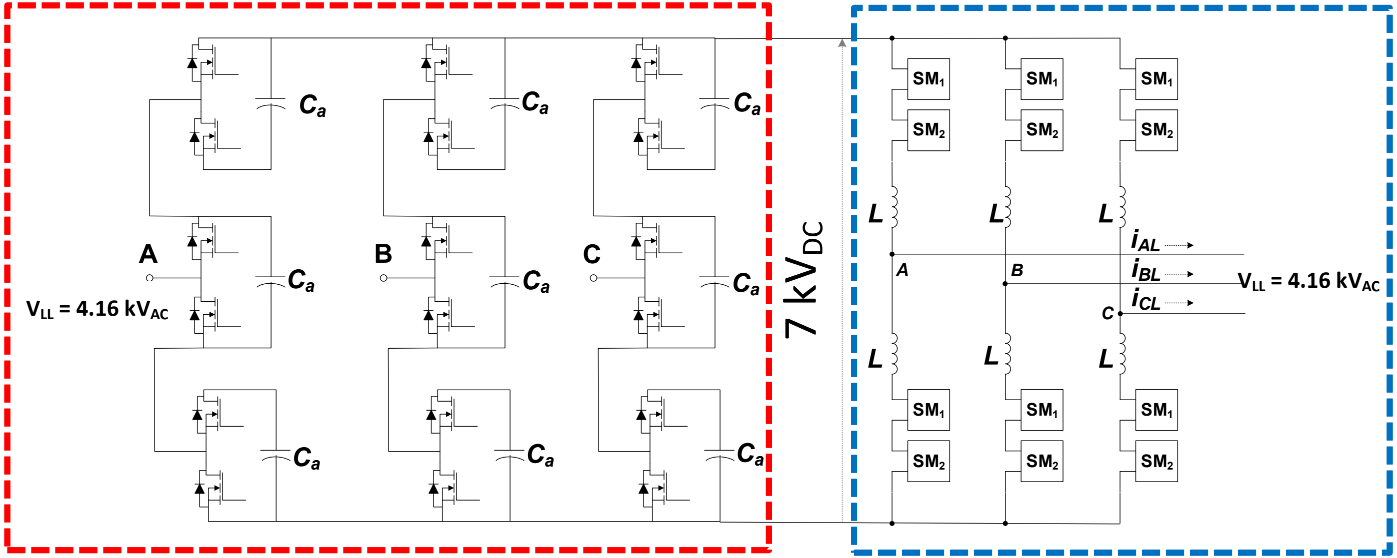
HPPE

THE OHIO STATE UNIVERSITY COLLEGE OF ENGINEERING



Funding provided by DOE Advanced Materials and Manufacturing Technology office

Back-to-back Converter Development



10kV SiC Devices

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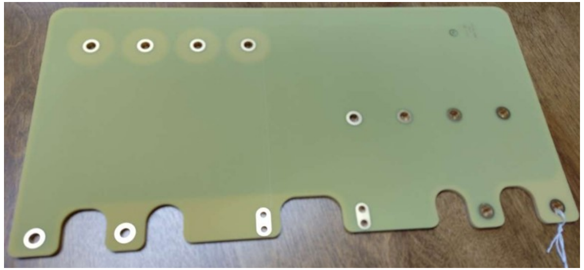
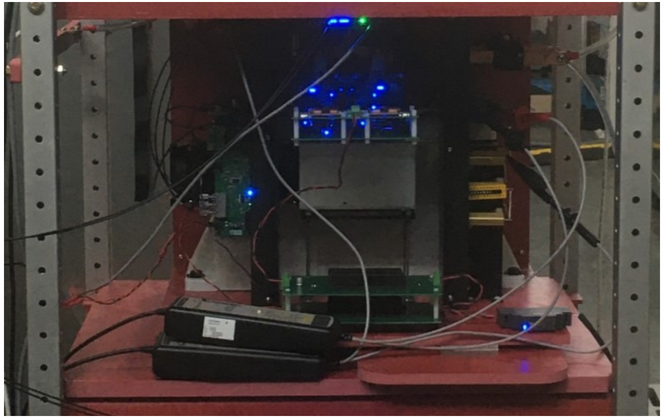
COLLEGE OF ENGINEERING

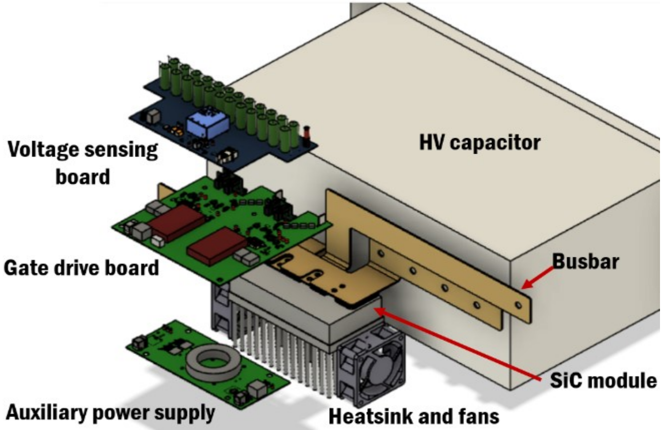
Converter Development

Bus Bar Assemblies



Auxiliary power supply



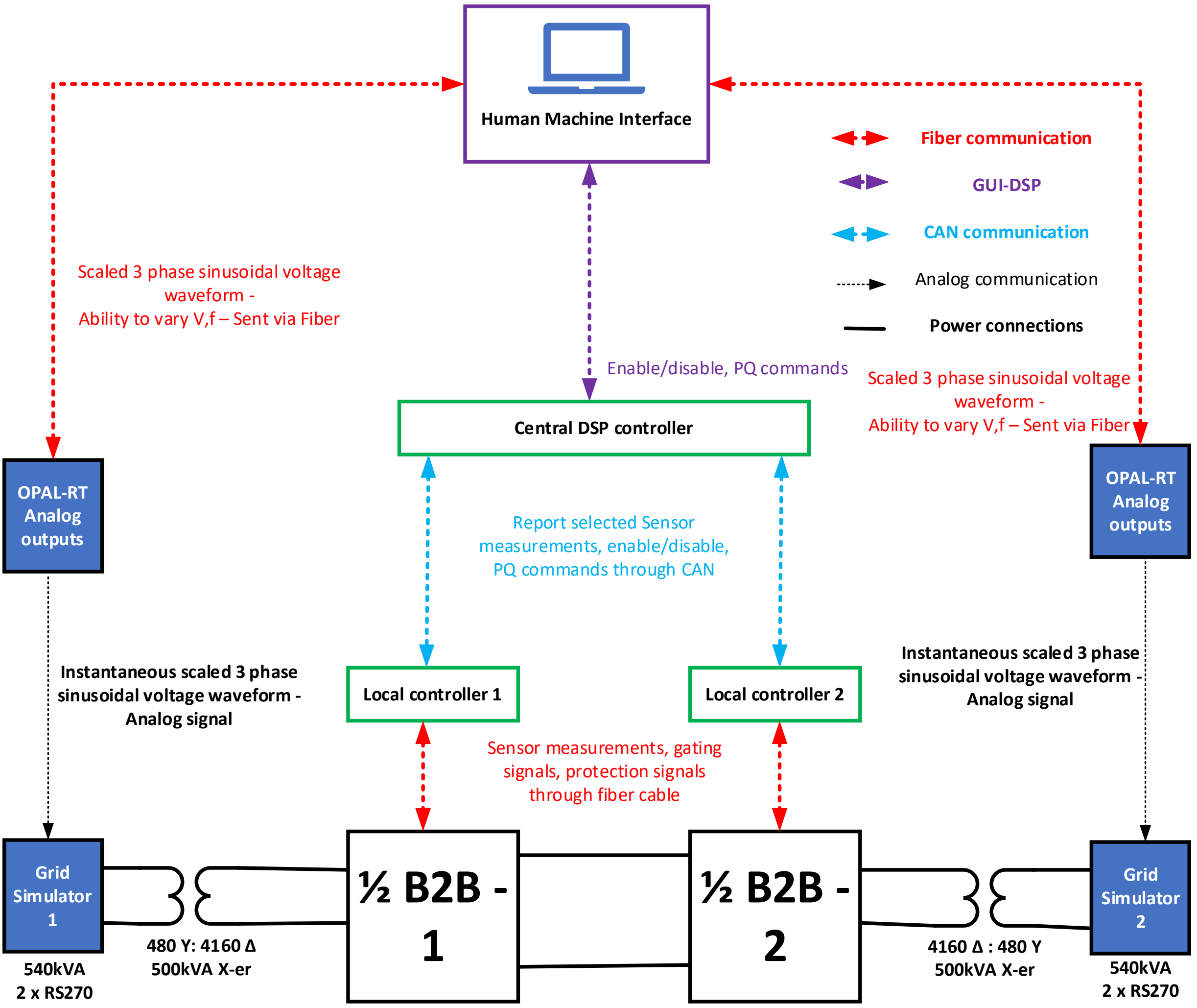


Three phase Converter pictures – Developed by academic partners

Ohio State MMC converter
330kVA @ 4160V AC

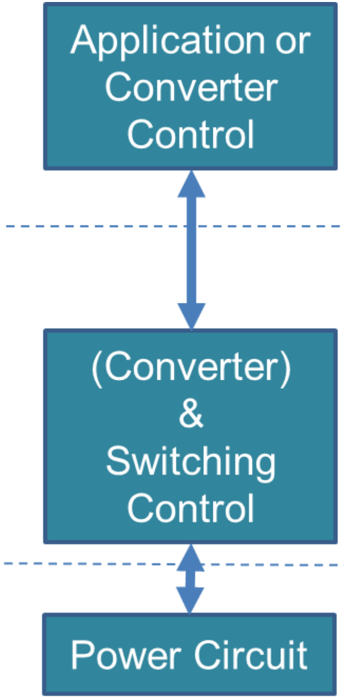
Florida State MMC converter
330kVA @ 4160V AC

Full converter testing



- Full converter tested at Energy Systems Integrations Facility (ESIF)
- Validation of AC-AC converter @ 4160V AC
- Verification of advanced grid converter controls
- Verify bidirectional operation of each ½ converter operation as a rectifier and an inverter

Power Electronic Converter in a Real System



System Control ≥10 ms
- Operating mode determination

Application Control 1ms - 1s
- Overriding control & measurements

Converter Control 10 us – 1 ms
- PLL synchronization
- Coordinate transformations
- Current controls
-

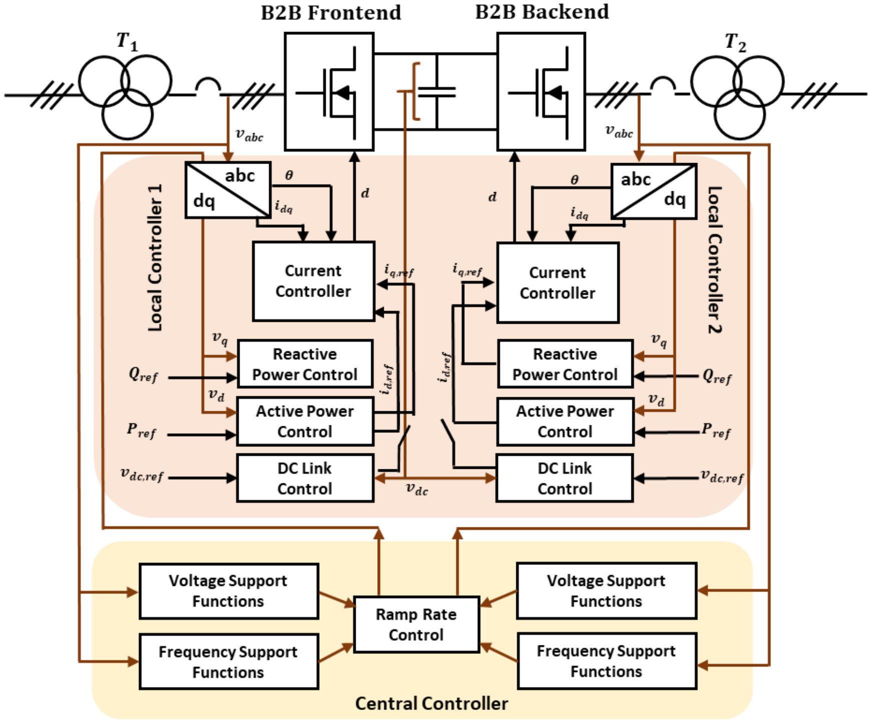
Switching Control 1 – 10μs
- Modulator
- Converter switching logic
- 2nd level protection

Hardware Control 0.1 – 1μs
- Stack or module assembly
- Snubbers for safe commutation
- Gate drivers and feedbacks
- 1st level device protection
- A/D and D/A conversion
- Gate drive power supply
- Current and voltage sensors
- AC/DC power terminals
- Thermal management

Control Implementation

Controller Development – Central Controls

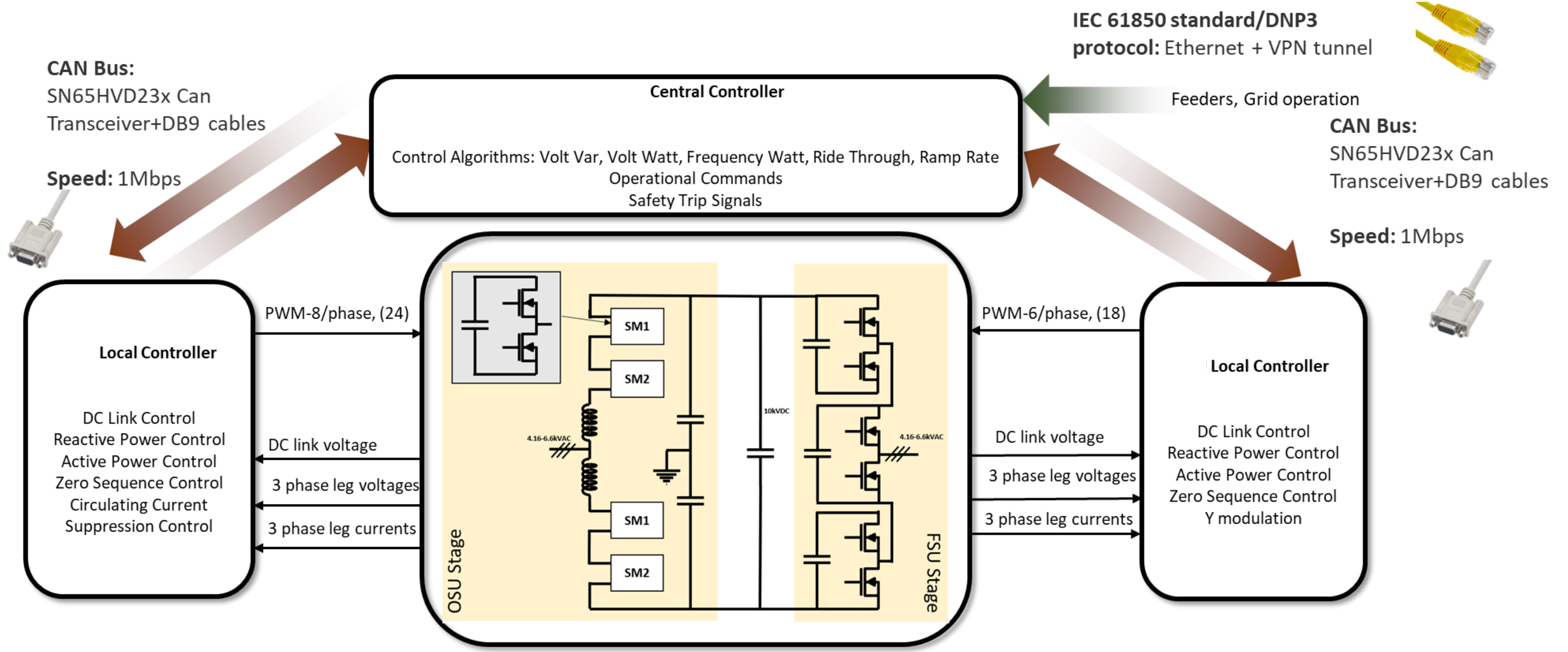
Central Controller Architecture



- A new decentralized hierarchical controller
- Local controllers - phase locked loop (PLL) synchronized averaged current controls
- Main controller - IEEE 1547 based inverter grid test functions including voltage support, frequency support, ride through and power curtailment controls
- Protection controller block is a subset of the main controller

Controller Development – Control Implementation

Control Platform Specification and Architecture



- Unified coordinated controller platform
- Modular enough for interfacing with any controller

WIBA

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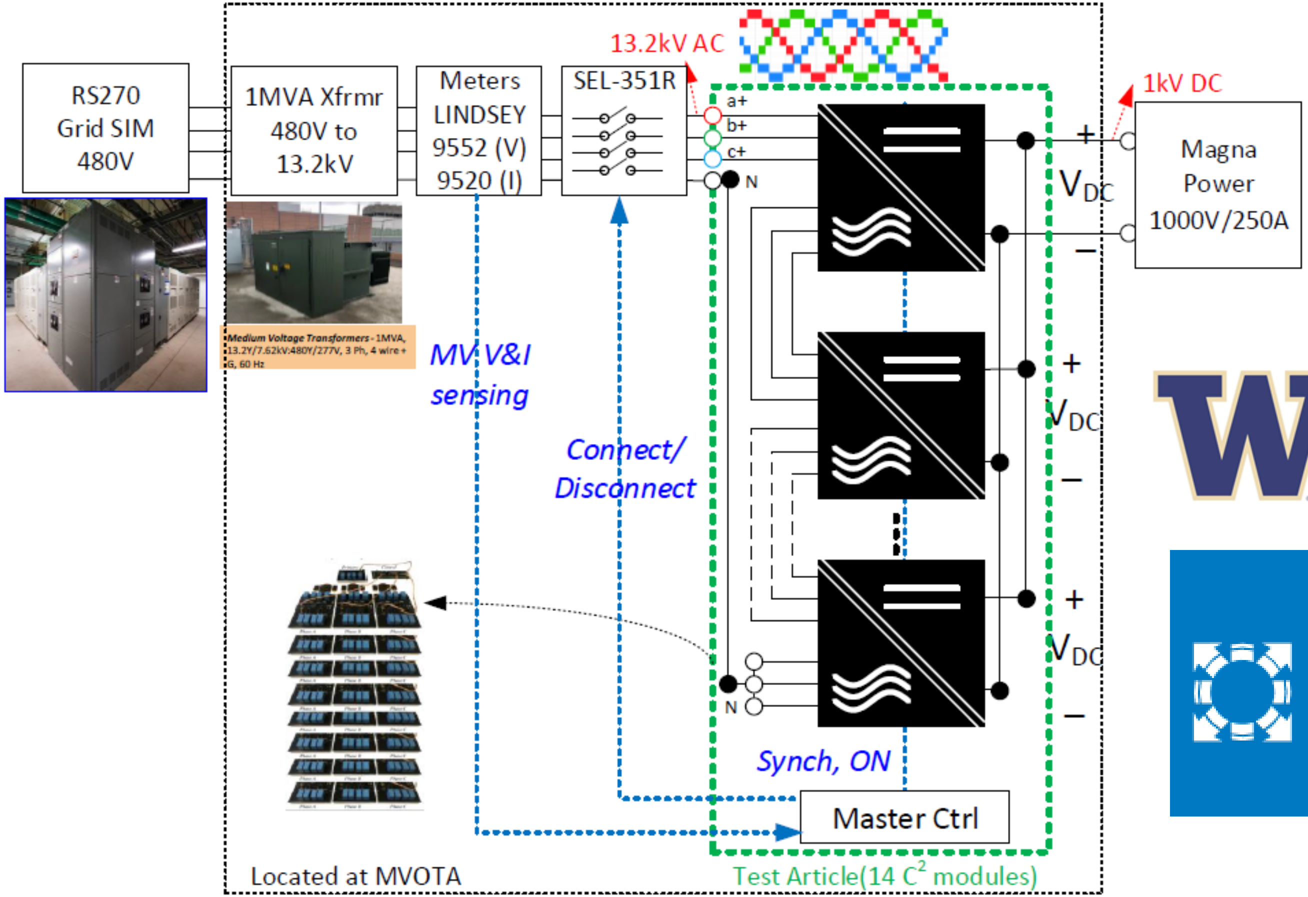
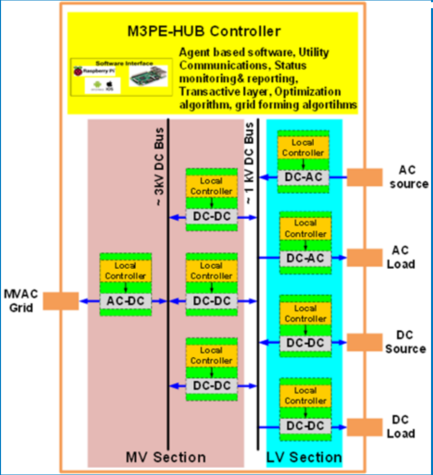
U.S. Department Of Energy



Transforming ENERGY

Multiport, modular, medium voltage power electronics system (M3PE-HUB)



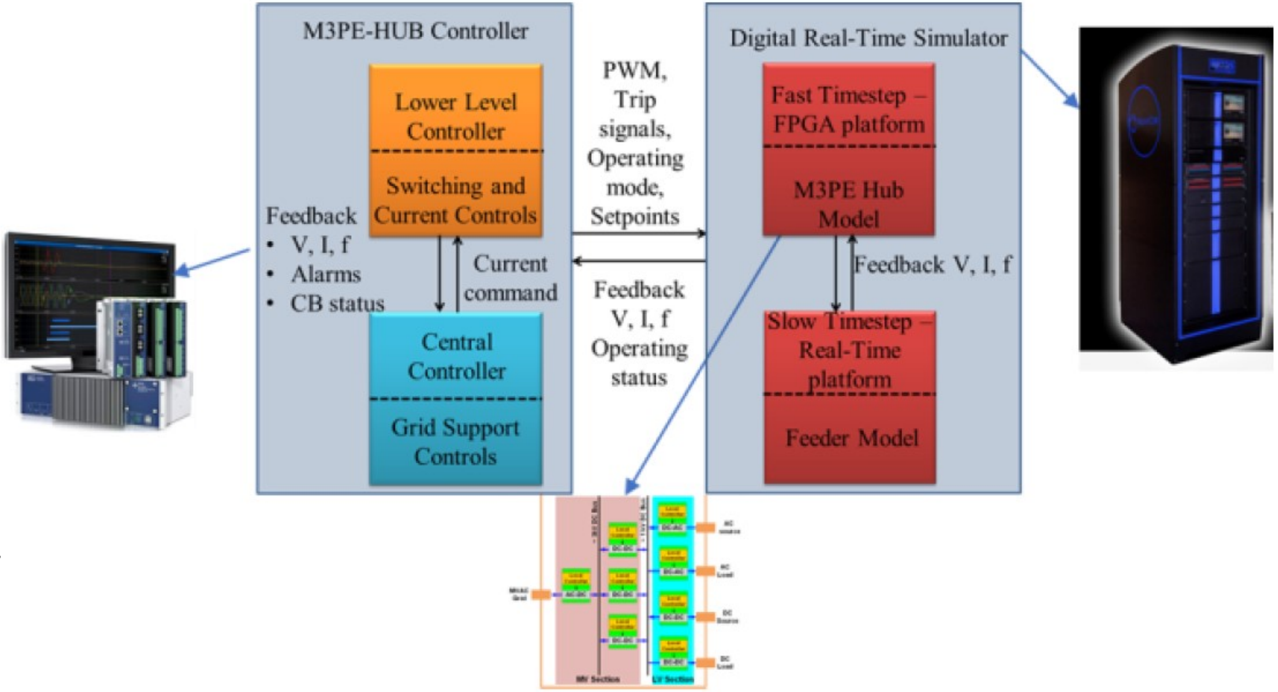
Funding provided by DOE Grid Modernization Initiative

Lead lab: ORNL
Partnering labs: NREL, NETL, and PNNL

M3PE hub controls

- Develop the advance smart power electronics hardware and software interfaces for grid applications.

- Design and develop and demonstrate direct grid connect Medium Voltage (upto 13.8 kV) Multiport power electronics “energ hub”.

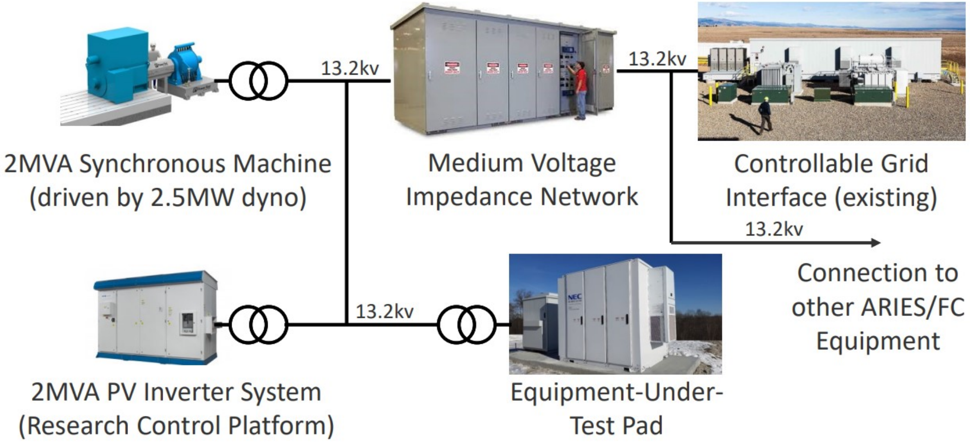


M3PE hub controls

- Multiport, modular, medium voltage power electronics system (M3PE-HUB) is being for futuristic grids.
- Verification of M3PE-HUB’s operating scenarios under important corner cases were identified and addressed.
- Preliminary case studies were performed via real time simulation in RSCAD with the M3PE-HUB connected to an existing model of Banshee microgrid.
- IEEE-1547 2018 based advanced grid functionalities are implemented for the M3PE-HUB in a central controller to have a better grid supportive functional operation.
- Several important case studies are being explored to realize the operational capabilities for the system either in grid following or grid forming modes

NREL MV Capabilities

Energy Systems Integration Facility
- Indoor MV test facility
- Real Time Digital Simulators
- PV emulators – 1.5MW
- Grid simulators – 2 MW



NREL Flatirons facility
- Upcoming MV test facility
  - PEGI (December 2023)
  - APET (2025)
- Test platform for MV converters with more flexibility

Conclusion & Other Contributions

- Impact of the advent of medium-voltage SiC devices for the power systems
- The combination of various standards on the control of these power converters
- Study of grid applications - quantification and demonstration of grid support functions enabled by addition of MVB2B converters to the power grid
- Final demonstration of the full system at the Energy Systems Integration Facility in NREL

Thank you

www.nrel.gov

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