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Designing Distributed Microgrid Protection Schemes for the Future

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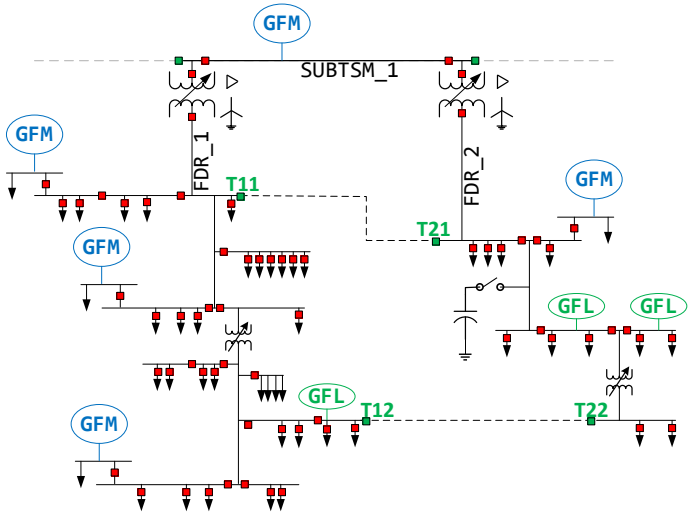
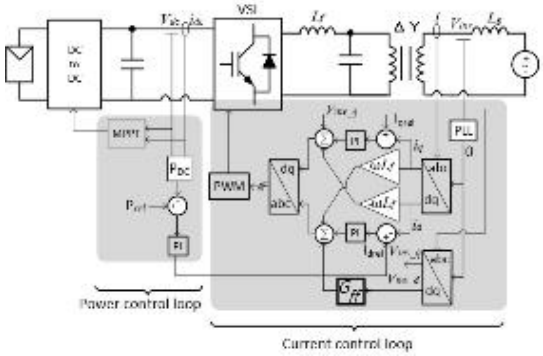
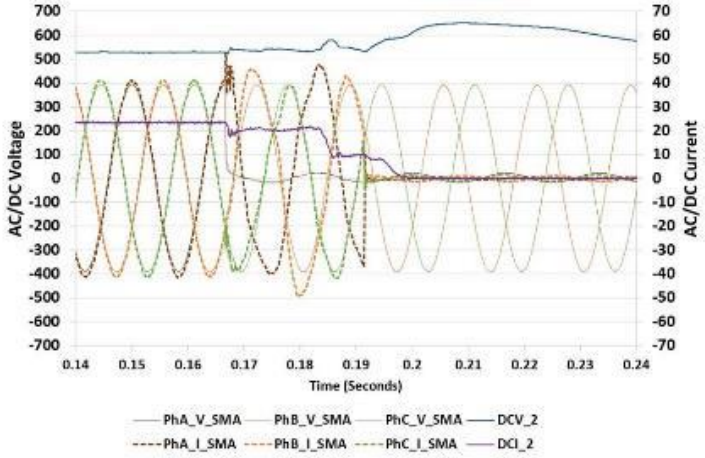
ISGT Latin America Panel Session “Exploring the Current Landscape and Future of Microgrid Control and Protection: Advancements, Obstacles, and Strategies”

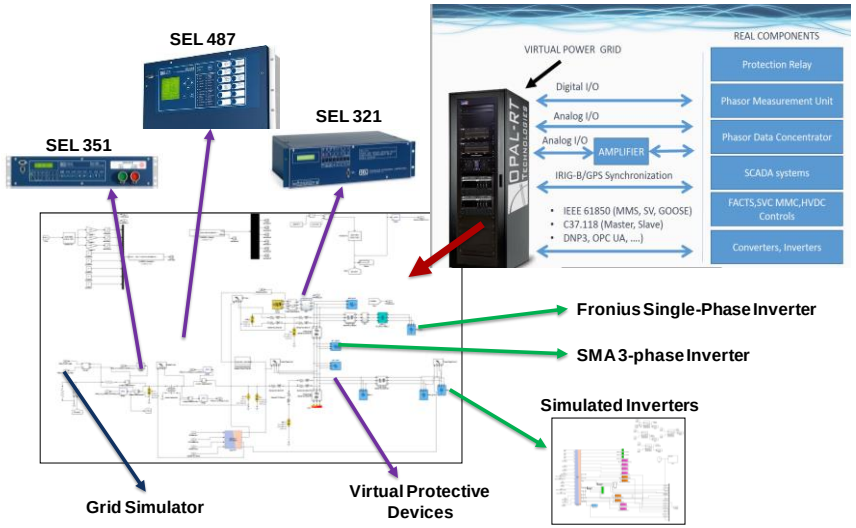
Microgrid Protection

- In order to provide reliability and resilience, microgrids must be protected and secure in grid-connected and islanded mode
- Microgrid protection is especially difficult for inverter-based systems because of the lack of models and inverters' low fault currents
- Developing, validating, and demonstrating highly reconfigurable communication-based protection schemes









Protection Design

Grounding Design

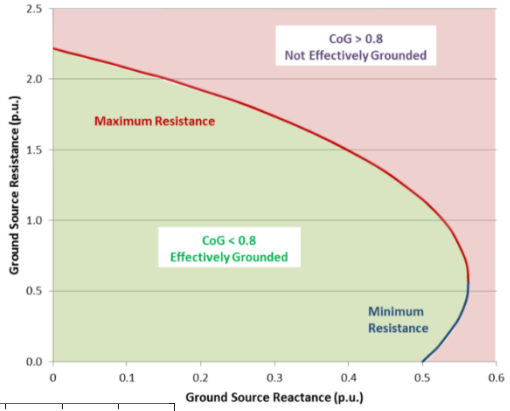
- Grounding is especially important for microgrid that transition from grid-connected to islanded with different ground sources
- Changing the ground resistance and reactance impacts the temporary overvoltages (that can damage equipment) and the ground currents during the fault (that determines the ability to detect the fault).
- Effective grounding calculations are more straightforward for synchronous generation, we can determine the correct size and model the impacts for the inverter-based microgrid using EMT simulations

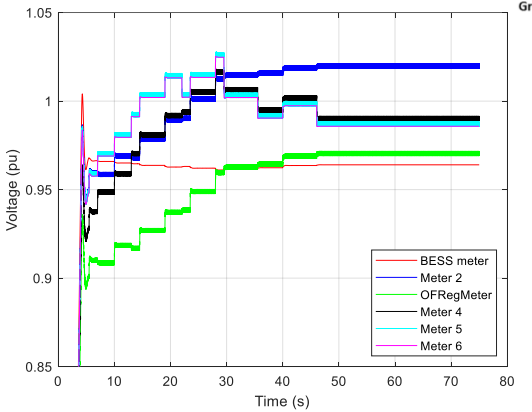
Black Start Design

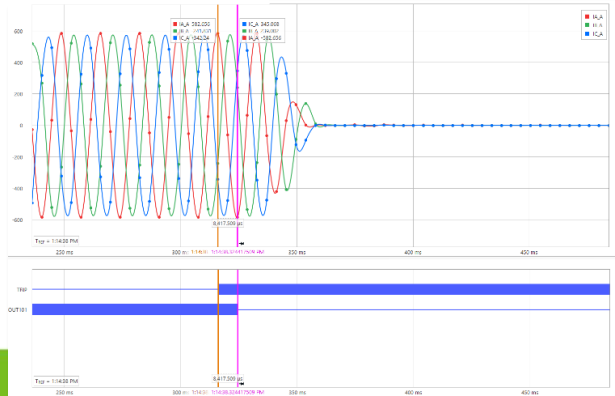
- Black-start of the bulk system or microgrids, including cold load pickup

For inverter-based microgrids, analysis often requires detailed EMT simulations

Validation can be performed with real-time hardware-in-the-loop (HIL)

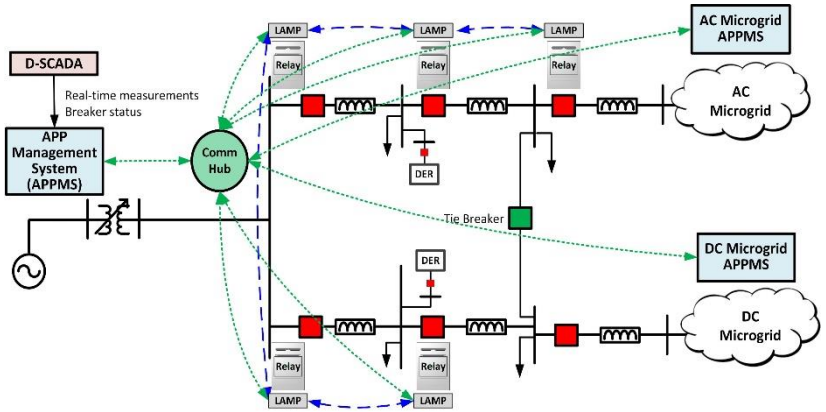


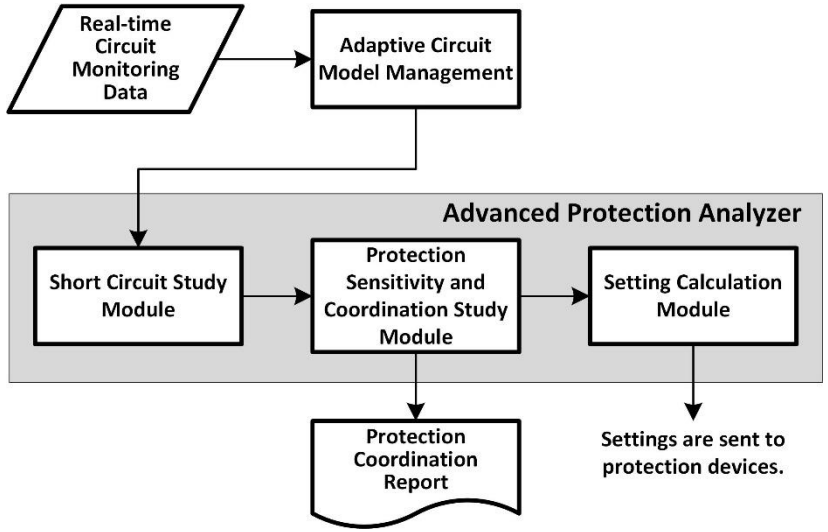




Adaptive Protection

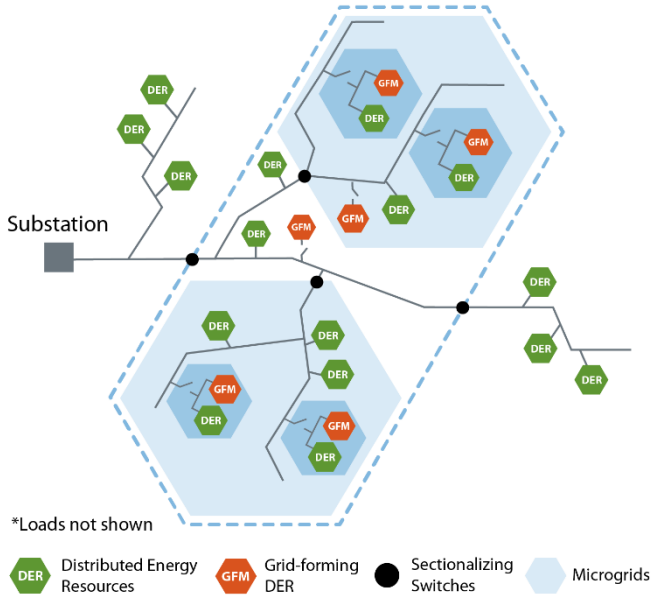
- Protection for dynamically changing systems and unplanned contingencies where settings may have to be modified when conditions change (reconfigurations, intermittency of renewables, etc.)
- Adaptive Protection Platform (APP) that optimizes the protection settings in real-time based on the grid configurations and state
- Streaming PMU data to APP that interfaces with PSS®CAPE to solve the expected fault currents for the current conditions. Based on the expected fault currents, the APP determines the optimal protection settings for all protection devices to maintain coordination, speed, and security.
- Demonstrated the adaptive protection with systems from several utilities

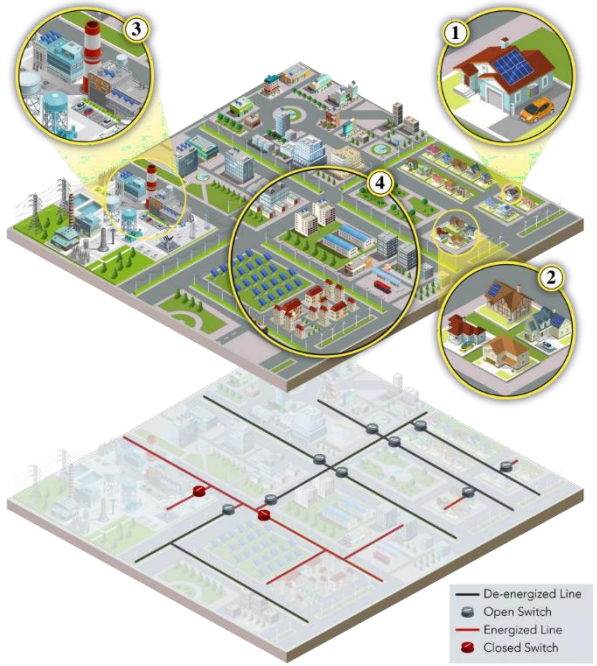




Protection of Networked Microgrids

- Designing protection systems for networked microgrids that are dynamically changing, have multiple points of interconnection, and flexible boundaries
- Protection system must be robust to varying amounts of synchronous generation vs. inverter-based generation, and changing levels of grid-forming vs. grid-following resources
- Protection design must be included in the restoration and black start algorithms and processes (self-healing)



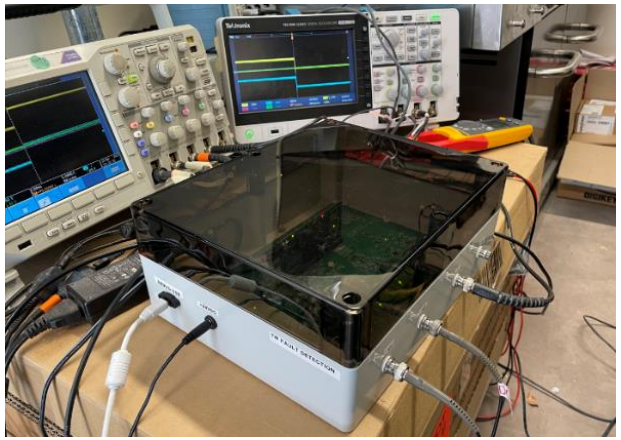


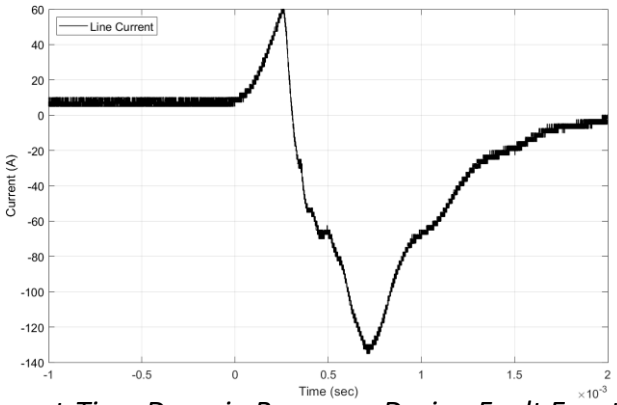
New Microgrid Protection Devices

- High-frequency traveling wave methods combined with physics-informed machine learning can learn correlations to determine the fault location
- Closed-form mathematical method for fault location in <10 microseconds using single-ended measurements
- Implemented in custom DSP hardware with 1 MHz sampling
- Deployed in DC microgrid on Kirtland Air Force Base for testing using fault generator

BlockEnergy Nanogrid Serving Residential Housing Loads

Ten-node BlockEnergy Microgrid on Kirtland Air Force Base





Current-Time Domain Response During Fault Event

Conclusions

- Microgrids will provide the building blocks for the fractal grid of the future
- New protection sensors, schemes, and communication will enable increased adoption and decreased cost of microgrids

Questions?

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