Resilient MVAC and Hybrid MVAC/MVDC Distribution Systems

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Goals and Objectives

- Development of a detailed reference system CHIL multi-platform simulation environment that combines together the ac and dc GRAPES challenge project networks into one interactive system to enable system resiliency studies.
- Determine and identify fault interruption, fault detection, isolation and recovery requirements and challenges and their impacts of Mvdc and Mvac voltage and frequency dynamics.
- Understand the how characteristic SSCB and HCB fault isolation times, current limitations and current limiting inductance affect Mvdc system performance (Year One)
- Provide a demonstration of a smart, resilient distribution system design process where the CHIL platform enables machine learning techniques and applies them to design of protection coordination (Year Two, but concurrent preparation activities)
- Investigate communication requirements for decentralized MVAC/MVDC multi-terminal networks.

Resilience and Protection Design Process

- Resilience cannot be directly quantified, but can be distilled into attributes, which can be further distilled into quantifiable metrics. Such attributes includes: Proactivity, Survivability (Susceptibility, Vulnerability, Recoverability), Repairability, and Sustantiality.
- Thus, the time required for the distribution system to isolate the fault, and the ability of the DERs to successfully ride-through the fault, to both increase post fault availability and aid in the fault recovery effort, can be traced back to Resilience.
- The protection settings must act within the DER’s ride-through capability, and the DER must ride-through while the protection schemes operate.
- An iterative design process is proposed to systematically coordinate protection settings of the distribution equipment and ride-through settings of the DERs to maximize the recoverability of the network, and thus the resilience.
- This design process is demonstrated on an islanded AC Microgrid to validate the process, protection scheme, and controls. The model was implemented in MATLAB/Simulink leveraging OPAL-RT accelerated simulation with an automated workflow to iterate quickly all the scenarios. This approach will be implemented in the multi-platform CHIL system, and the main electrical system will be implemented in Typhoon.

Coordination of Protection and Ride-through settings

- Fault Characterization:
  - Time-trip curves
  - Phase angle for directional settings
  - Time to maintain synchronization

Modeling & CHIL Implementation

Leverage strengths of strengths of real-time simulations platforms:

- Typhoon-HIL: Easy to implement power electronics-based distribution system in real-time.
- National Instruments-PXIe: Implement auto-code generated, FPGA-based controllers for elements of interest to simulate at higher TRLs, or which require faster controls/logic, such as AC/DC converter controls and gating, SSCB time response and logic, or protective relaying logic.
- OPAL-RT: Easy to run real-time Simulink-based DER controls in for less critical elements such as peripheral DERs and constant power loads.

Conclusion and Future Work

- This project successfully demonstrates a protection design process using an islanded AC microgrid with both a Genset and PV farm. This process and coordination of protection settings for distribution equipment, and ride-through settings for DERs. Future work will extend this to include the network can successfully isolate faults operating under grid-forming energy storage as well.
- The impact of SSCB and HCB inductance of MVDC system stability has begun, building on GR-18-08. Future work will continue to gain incite and understanding of stability and network performance impact and trade of SSCB inductance and topology.
- Both the AC and DC networks presented here will be combined and implemented the CHIL system shown above.
- Collaboration with GRAPES Korea will begin to understand their knowledge and experience on MVDC distribution systems.