NSF Center for GRid-connected Advanced Power Electronic Systems (GRAPES)

GR-17-02 Development of Protective Relaying Methods for Microgrids

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Overview of Research Need

Microgrids require protective systems and power converters interfacing to distributed energy sources and loads to work in a coordinated fashion under all kinds of fault conditions.

Achievement of reliable fault discrimination in microgrids is one of the main factors that drives up development costs of microgrids because each system becomes a custom design because of the following:

- Multiple potential energy paths during fault scenarios
- Impacts of source and load capacitances and cabling creates a complex interdependence between system layout, stability and fault response
- Time-trip requirements are compressed in much shorter time scales leading to need for fast acting protective device and low latency fault detection and location

Future microgrid relaying systems will require optimal allocation of protective functions between converters and protective devices, high speed communications at secondary control layer levels of the system and distributed knowledge of the dynamically changing system configuration.

AC Microgrid: In islanded mode the inverter current capability is too close to the time-trip characteristics of commercially available MCCBs.

DC Microgrid: The Fault is Characterized by the system capacitance and cable inductance, so the device must be able to act very quickly to limit current during sudden fault inception current surge that is characterized by the connected bus capacitance and cable inductance to the fault.

\[ i(t) = \frac{v_c(0)}{L} \cdot \omega_d \cdot e^{-\alpha \cdot t} \cdot \sin(\omega_d \cdot t) \]

where

\[ \omega_d = \sqrt{\omega_o^2 + \alpha^2} \]
\[ \alpha = \frac{R}{2 \cdot L} \]
\[ \omega_o = \frac{1}{\sqrt{L \cdot C}} \]
Proposed Novel Approach

- Critical to understand reliability and timing of communications
- Primary control speeds (i.e. > 10kHz) move up to secondary control levels

CHiL Test Setup for Validation of High Speed Protection Methods

1. CHiL systems at UWM and USC that include high speed communications for protective relaying and pilot protection
2. PHiL demonstrations of “unit-based” protective schemes for DC microgrids utilizing MMC-based AC to DC converter and MPSST-based DC to DC converter
3. Develop understanding of the methodologies for microgrid protection and distinctions between requirements for AC, DC and hybrid AC/DC microgrids
4. Develop high speed communication protocol for microgrid protection
5. Provide inputs to standards for microgrid protection
6. Pursue follow-up research programs targeting specific industries with industrial partners
7. Will lead to three new conference papers and four transactions paper submissions

Confidential – Semi-Annual Meeting – Nov. 2015
Incorporation of High Speed Protective Relaying into CHiL and PHiL Systems at USC and UWM

Controller

Controller

Controller

Controller

Opal-RT

CompactRIOs

OC-48 SONET ring

Host Workstation and Visualization

Opal Workstation

Network Simulation and Emulation

NS-3RT Apposite N-91

Router

UTILITY GRID

High Speed Link

Controller
Present Capabilities

**USC**
- Power system and communication RT simulation/emulation: Opal-RT, NS3-RT, Apposite N-91, OC-48 SONET ring
- Platforms for HIL testing of distributed monitor-control (eleven high performance CompactRIO, six multi-purpose embedded units, Kintex 7 FPGA platform)
- Linear PHIL interfaces (15kVA, up to 200kHz bandwidth) and PV emulator
- Highly reconfigurable DC/AC micro-grid (nine 75kVA converters, several motor drives and passive loads, one 60kVA MMC)

**UWM**
- Power system and communication RT simulation/emulation: PSCAD, Opal-RT, RTDS
- Labview and CompactRIO for testing of distributed monitor-control in microgrids
- 250kVA AC Microgrid
- 480Vac/380Vdc Hybrid AC/DC Microgrid (presently under development)
- 100kW solar PV, 12kW wind turbine, 114kW Li-Ion storage, two 45kW natural gas generators, active and passive loads, and grid-side static switch