Microgrids - Hardware Testing and Standards Development

Ben Kroposki
Distributed Energy Systems Integration
National Renewable Energy Laboratory
Microgrids – Improving Grid Reliability
Development of High-Speed Static Switch for Microgrid Applications

- NREL, Northern Power Systems, and California Energy Commission developed at DER Switch

- Circuit Breaker, SCR, and IGBT hardware with same controller

- Tested CB and controller equipment at Northern and NREL

- SCR based unit installed in CERTS microgrid
DER Switch

Flexible DER Interface System

Area Electric Power System

Flexible DER Interface System

Power Network Aware DER Asset

DER Power Network Block Diagram

MTR Meter
PCC Point of common coupling
SG Switch gear (Power module)
PD Power distribution (Power module)
PR Protective relaying (Control module)
M&D Monitoring & dispatch (Comm. module)
PM Prime mover
GE DER Generator
PC Power Conversion
LC Local DER device control
L Loads

WEB
DER Switch – Possible Configurations

Circuit Breaker

SCR

IGBT
Testing on DER Switch

**Relay Function Testing**
- Undervoltage (27)
- Overvoltage (59)
- Overfrequency (81O)
- Underfrequency (81U)
- Phase sequence (46)
- Instantaneous overcurrent (51)
- Time overcurrent (50)

**IEEE 1547 Testing**
- Over/undervoltage
- Over/underfrequency
- Synchronization
- Reverse power
- Unintentional islanding.

**Power Quality Testing**
- CBEMA-ITI curve

Omicron CMC 256 – Secondary injection test set

Utility Grid Simulators – Primary injection test set
CBEMA-ITI Curve Testing

- CBEMA
- 3-phase change
- Va change
- Vb change
- Controller Settings

Single-phase PLL response error
### IEEE 1547 Series Standards

**1547-2003** Standard for Interconnecting Distributed Resources with Electric Power Systems

**1547.1-2005** Conformance Test Procedures for Equipment Interconnecting DR with EPS

### Current Projects

- **P1547.2** Application Guide for IEEE 1547 Standard for Interconnecting DR with EPS
- **P1547.3** Guide for Monitoring, Information Exchange and Control of DR
- **P1547.4** Guide for Design, Operation, and Integration of DR Island Systems with EPS
- **P1547.5** Guidelines for Interconnection of Electric Power Sources Greater Than 10 MVA to the Power Transmission Grid
- **P1547.6** Recommended Practice for Interconnecting DR With EPS Distribution Secondary Networks

### Future Projects

- DG Specifications and Performance
- Guide for Interconnection System Certification
- Guide for Grid/DG Impacts Determination
- Guide for DR Power Electronics

### Microgrids

- Urban distribution networks
IEEE P1547.4 (Draft 2)

Figure 1. Description for Substation, Bus, Circuit, Circuit Lateral, Facility, and Adjacent Circuit Islands
4.0 Electrical System Characteristics
   4.1 DR Island System Overview
   4.2 Characteristics of loads
   4.3 Characteristics of EPS (Local and Area)
   4.4 Characteristics of DRs and interconnection systems
   4.5 Methods of DR voltage regulation and frequency control
   4.6 Area EPS Fault Clearing
   4.7 Methods for detecting Islands

5.0 Functionality of the DR Island System
   5.1 EPS connected (normal parallel operation)
   5.2 Transition to island mode
   5.3 Island mode
   5.4 Reconnection mode

6.0 Planning and Engineering of DR Island Systems
   6.1 Load Requirements
   6.2 Electric Power System (EPS) Planning
   6.3 Systems Studies
   6.4 Additional Planning Considerations
   6.5 Testing and Commissioning

7.0 Operation and Management of DR Island Systems
   7.1 Protection Consideration
   7.2 Central Dispatch Control Case
   7.3 Distributed Dispatch Case
   7.4 Communication and information exchange
   7.5 Operating the system on a real time basis
   7.6 Time length of operation