Microgrid Switch Technology
DOE Microgrid Workshop Session 1

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Session Goals

1) Review General Switch Functionality

2) Review Switch Types and Cost/Benefits

3) Identify Research & Product Development Areas of Greatest Value to MG Switch Advancement
   a. Cost reduction opportunities
   b. Technical challenges to reduce cost or enhance performance
   c. Most needed R&D focus areas

4) Additional Information (Backup)
Introduction of Co-Chairs

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General Switch Functionality
“Disconnect” Functionality

- Key requirements set by IEEE 1547, primarily addressing issue of utility backfeed from DER.
- Simple (concept) disconnect switch with synchronizing capability to re-connect to utility.
- Requires fast control coordination with microgrid resources, or droop-based system.
- Can use active or passive synchronization (depending on DER controls).
- Load management controls probably are not fast enough to shed load and start up recip-based DER in time to avoid load interruption.
- Could be implemented with mechanical or electrical (static) switches.
“Transfer” Functionality

- Transfer between sources (grid and local generation) to provide and maintain power to load.

- Must manage paralleling DER with grid if DER allows. Manage DER source taking over grid-forming role to meet load.

- If DER is online, transfer may be competed fast enough to avoid load interruption.

- Depending on DER type and characteristics of load, traditional mechanical or high-speed electrical/static transfer switching should be selected.
“UPS” Functionality

- Disconnect switch functionality integrated with battery for short duration coverage of load during islanding events.

- Seamless transfers - represents versatile switch solution that gives flexibility in timing to bring DER online and accomplish load management

- Grid reconnection requires passive or active re-synchronization of the DER asset(s)

- Expensive solution – driven by high cost of large inverters & battery storage
Switch Types
Circuit Breaker-Based MG Switch

- Reliable, time-tested solution
- Relatively inexpensive
- Off the shelf components
- Designed to open under fault conditions, or withstand fault current up to 30 cycles (ANSI rated devices)
- 3-5 cycle operations
- Can use multiple protective relay vendors
Contactor-Based MG Switch

- For sustained operation of DER in parallel with utility grid, breaker-based or static-type ATS is preferred.

- If DER is normally offline as backup to Utility grid, breakers (MV, LV) or LV Contactor-based ATS are preferred (static-type provides little benefit).
  
  - Breakers: MV or LV types. Switching + Overcurrent protection (O/C) same device. Good fault withstand capability.
  
  - LV Power Contactor ATS: Reliable switching, but require upstream O/C protection. Limited fault withstand capability.
Static MG Switch

- Relatively expensive
- Needs CB to handle fault conditions
- Very fast operations (less than 1 cycle)
- Often custom designed
- Often employed in MG’s when large-scale battery storage operates in parallel with utility supply
## MG Switch Summary

<table>
<thead>
<tr>
<th>Switching Device</th>
<th>Open/Close Speed</th>
<th>Cost</th>
<th>Pros</th>
<th>Cons</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit Breaker</td>
<td>3-6 cycles</td>
<td>Low-Med</td>
<td>• Additional protection not required</td>
<td>• Not suited for repeated open/close cycles</td>
<td>Siemens, ABB, GE, Eaton, etc.</td>
</tr>
<tr>
<td>Contactor</td>
<td>3-6 cycles</td>
<td>Low</td>
<td>• Rated for repeated open-close cycles</td>
<td>• Requires additional circuit breaker for fault current protection</td>
<td>GE, ASCO, Russelectric</td>
</tr>
</tbody>
</table>
| Thyristor        | Sub-cycle        | High  | • Very fast  
• Can handle many open/close cycles | • Requires circuit breaker for fault current protection | Thomas & Betts, Eaton, L-3, S&C, Cyberex |
Microgrid Switch Development Discussion

• Costs
• Research & Development Needs
• Technical Challenges
• Decide on focus areas
1. **Intentional Planned Island**
   - Planned event to disconnect from grid
   - DER can be configured; reciprocating sources turned on and synchronized, and load management configured prior to islanding
   - DER sources run in parallel with grid for short time
   - Intended to be seamless transfer
   - Realizable with any type of switch

2. **Grid Synchronization and Reconnection**
   - Always planned
   - Seamless transfer
   - For passive synchronization (droop), a static switch may be required
   - For active synchronization, any type of switch will work as long as it has control of the MG frequency and voltage

3. **Unplanned Islanding**
   - Unexpected loss of grid due to outage or poor power quality
   - If DER is running and exceeds load, a static switch can disconnect with no load interruption; a circuit breaker or contactor may cause short-term power quality issues or load interruption (3 – 6 cycles)
   - If DER is not up and running, interruption of power or poor power quality will be experienced, no matter what type of switch is used.
Discussion Topics

• Power Quality and stability concerns on disconnection and re-connection of MG from/to utility
• Passive vs. active synchronization schemes for MG re-connection to utility
• When is a static switch required?
• Controls coordination with switch (especially with active synch)
• Protection coordination requirements (trip curves, faults, etc.)
• Integration and operation considerations of power sources with inverter front end
• Use of IEEE 1547-compliant grid-tie inverters and/or advanced battery storage in island mode?
• Droop capability of traditional reciprocating assets – impact on island mode operation with other DER assets. Does passive (droop) synchronization require a static switch?
• Role of enterprise level controls and intelligent load shed/add logic in MG switch design
Cost Reduction Discussion

- What are today’s costs?
  - Static Switch $200k - $300k?
  - Circuit Breaker $50k - $100k?
  - Contactor $50k - $150k?

- Passive vs. Active synchronization… When is active synchronization required? Is active sync using a less costly switch (circuit breaker) than passive synchronization using a static switch?

- Can cost be significantly reduced? 50%? 10%? What are reasonable cost targets?

- What are the technical challenges of the discussed cost reductions? What (if any) research is needed to achieve cost targets?

- How do we get the costs out? Streamline functionality?

- How do we maintain or improve performance while reducing cost?
Research & Product Development Needs

- Are there opportunities to get cost out of static switches?
- When and why are static switches needed?
- Decision guidelines to support switch selection (based on site-specific DER and operational requirements)?
- Integration with low energy, high power energy storage?
- Protection coordination?
- Controls standardization and integration with other microgrid components, sending setpoints, mode signals, etc. to DER?
- Microgrids utilizing only renewable assets

- Brainstorm and list R&D topic areas
- We will record all ideas and vote on the winners
Research Idea Checklist

**Baseline Performance**
- Technical functions or capabilities for current applications
- Costs for current applications
- Limitations for target applications (current and future)

**Performance Targets**
- Technical functions or capabilities for target applications
- Costs for target applications
- Why the performance targets are needed
- Significance and impact of the performance targets with respect to achieving the DOE microgrid targets

**R&D activity**
- R&D scope
- R&D milestones, cost/performance targets, and their schedules
- Transformational R&D components (a strong role for DOE)
- DOE and non-DOE (other federal agencies, state/local governments, industry, universities, national labs) roles in the activity
- Uniqueness of this project and/or synergy to other ongoing projects?
End Main Presentation

Thank you for your participation
Additional Backup Material

• System Architectures
• Static Switch Designs
• NREL Microgrid Switch Testing
Traditional “peak shaving” or backup power utilizing reciprocating assets.
Application Example 2

Addition of grid-interactive PV/solar power on-site generation.
Application Example 3

Addition of energy storage, with grid-Interactive or grid-independent PV capability.
Integration of energy storage with MG switch.
Multiple combinations of reciprocating and inverter-based assets along with energy storage.
SatCon Static Switch Configurations

**Figure 1:** Double (Common-Bus) MV STS

**Figure 2:** Triple (Split-Bus) MV STS
Cutler-Hammer Static Transfer Switch

Cutler-Hammer Metal-clad or Metal-enclosed Switchgear Medium Voltage Subcycle Transfer Switch (MVSTS)

Source 1

N.O. B1
N.C. M1

Static Switch #1

Static Switch #2

N.C. M2
N.O. B2

Load Bus

Load

Source 2

Figure 1. Typical 2-Mains, Common Load Bus Configuration (See Figure 3 for equipment layout)
Example Testing at NREL

System Name: ASCO 7000 Soft Load Transfer Switch

Year Tested: 2003

Researcher: B. Kroposki

Technology: Closed-Transition Transfer Switches, typical application to emergency power systems

NREL Test Objectives: Validate IEEE 1547 Interconnection Standard test procedures
Example Testing at NREL

System Name: DER Switch
Prototype (with CEC and NPS)

Year Tested: 2006

Researcher: B. Kroposki

Technology: Electrically-controlled molded case circuit breaker

NREL Test Objectives: Design and test integrated intelligent switch and system controls for DER connection to utility grids
Example Testing at NREL

System Name: GE Universal Relay

Year Tested: 2008

Researcher: S. Chakraborty

Technology: Electrically controlled circuit breaker

NREL Test Objectives: Verify functionality of DG generator voltage/frequency control
Two microgrid systems are planned for testing at NREL in 2011.

1) SMUD Microgrid System: Static droop sync switch, InVerde TecoGen Natural Gas Co-Gen Units

2) PGE Microgrid System: Vista switch, Battery/Inverter System, Diesel Generation