Microgrid Interconnection, Islanding and Blackstart Do’s and Don’ts

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February 11, 2020
Agenda

► Utility Interconnection Considerations
  • Voltage Level, System Grounding, Protection, Import/Export Restrictions

► Microgrid Islanding Considerations
  • Planned vs. Unplanned, Loading and Load Shed, Electrical Distribution

► Microgrid Blackstart Considerations
  • Microgrid Asset or Not, Load Step Limits, Parallel Operation with DER
Basic Structure of the Electric System

Color Key:
Blue: Transmission
Green: Distribution
Black: Generation

Transmission Lines
500, 345, 230, and 138 kV

Generating Station
Generator Step Up Transformer
Transmission Customer
138kV or 230kV

Subtransmission Customer
26kV and 69kV

Substation Step-Down Transformer
Primary Customer
13kV and 4 kV

Secondary Customer
120V and 240V
Interconnection Voltage Level

► Transmission
  • >69,000V
► Primary Distribution
  • 12,470V – 34,500V
► Secondary Distribution
  • 208Y/120V – 4,160V
System Grounding

► Utility System
  • Typically 3-Phase 4-Wire Multipoint Grounded Wye

► Campus Distribution System
  • 3-Phase 3-Wire Solidly Grounded Wye
  • 3-Phase 4-Wire Solidly Grounded Wye
  • 3-Phase 3-Wire Low Impedance Grounded Wye
  • 3-Phase 3-Wire Ungrounded

► Interconnection Transformer(s)?
Isolation Transformer at Interconnection

- Delta-Wye
  - Eliminates Ground Current Contribution to Utility
- Wye – Wye
  - Eliminates Overvoltage Potential/DER Wye or Delta
- Delta-Delta
  - Eliminates Ground Contribution to Utility/DER High Impedance Ground
- Wye-Delta
  - Eliminates Overvoltage Potential/DER High Impedance Ground
Utility Protection Requirements

► Protection Requirements Differ by Utility
► IEEE 1547 Requirements
  • An Attempt to Standardize <10MVA
  • Primary and Secondary Interconnections
► Anti-Islanding Protection
  • Direct Transferred Trip
  • Reverse Power 32
    (Non-Export Applications)
Additional Protection Requirements

► Additional Protection
  • Over/Under Voltage 27/59
  • Over/Under Frequency 81O/U
  • Directional Overcurrent 67, 67N
  • Ground Overvoltage 59N
    ► Utility Interconnection Delta-Wye
  • Sync Check 25
Import/Export Restrictions

- System Minimum Load > Generator Output = Import
- System Minimum Load < Generator Output = Export
- Exporting (Even on a Rare Occasion) Requires Market Participation
  - Additional Metering Requirements
  - Subject to Market Rules and Pricing
  - Location Dependent – Rules Vary
- Potential Islanding Impact

![Diagram showing import/export scenarios and stability levels]

- Stable
- Unstable
- Not Tested

**Diagram Notes:**
- Import values range from -2.0 to -1.5.
- Export values range from 6.45 to 6.50.
Microgrid Islanding

► Planned Islanding
  • Deliberately Separate from Utility
  • DER Capacity Must Exceed Load
  • DER Operate in Frequency Control (Isochronous) Mode
    ► Maintain 60Hz
    ► Share Load if Multiple DER Installation
  • Manual or Automated Initiation
Microgrid Islanding

► Unplanned Islanding

• DER Energize a Portion of the Utility System Following a Utility Outage
• DER Must Automatically Separate from Utility
• Separation Must Occur Before Utility Reclosing

► Separate Entire System and Operate in Island Mode
  ▪ Trip Utility Interface Breaker(s)

► Separate DER Only
  ▪ Trip DER Breaker(s)
  ▪ Trip Specific Feeder Breaker(s)
Microgrid Islanding

► Electric Load Controls DER Frequency
  • Transition DER Control - Isochronous Control
► Frequency Must be Maintained
  • Serve Critical Electrical Functions
  • Low Frequency = Overload
    ► Can Cause DER Trip
  • High Frequency = Underload
    ► Can Cause DER Trip - Overspeed
Loading and Load Shed

- Islanding with Load $<$ Generator Capacity Requires DER Output Reduction
  - Monitor Individual DER Output and Load
  - Turn Down DER Output to Maintain 60Hz
  - Shutdown Excess DER
  - Control Load Additions – Load Step Restrictions
Loading and Load Shed

► Islanding with Load > Generator Capacity Requires Load Shedding
  • Automated Load Shedding Required – Options:
    ► Frequency Based
      ▪ Shed Load Until 60Hz can be Maintained
      ▪ Rate of Frequency Decline
      ▪ Prioritized
    ► Load/Capacity Based
      ▪ Monitor Load and Online DER Capacity
      ▪ Shed Load to Below Online DER Capacity
Islanded Electrical Distribution

► Electrical Distribution System Configuration
  • Access to all Plant Auxiliary Loads
  • Access to Critical Loads
  • Sufficient Load to Maintain Stable DER Operation
► System Protection and Coordination
► Grounding When Islanded
  • Ground Fault Coordination
  • Potential for Ungrounded Feeders
Islanded Electrical Distribution

► Ungrounded Island
  • Connect Zig-Zag Grounding Transformer to Island

► Inverter Based Generation
  • Very Low Short Circuit Current Available When Islanded
  • Incorporate Communication-Assisted Tripping

► Zone Interlocking
Microgrid Blackstart

► Microgrid DER Asset
  • BESS
    ► Grid-Forming
  • Reciprocating Engine Generator
  • Other DER?

► Non-Microgrid DER Asset
  • Standby Generator
  • Emergency Generator
Microgrid Blackstart Loading

► Load Shed Before Blackstart
  • Blackstart DER Capacity < Connected Load
  • Blackstart Auxiliaries Served
  • Beware Blackstart DER Load Step Limitations
    ► Diesel Generator – 100%
    ► Natural Gas Reciprocating Engine-Generator – 15 – 25%
    ► BESS – Power Rating
Microgrid Blackstart Parallel Paralleling

- Blackstart DER Parallel with Other DER
  - Not Issue if Microgrid DER Asset
  - Sync to Microgrid DER Once Started
  - Operate in Parallel with Microgrid DER
  - Transfer Load to Microgrid DER
  - Automated vs. Manual
SUMMARY

► If you’ve Seen One Microgrid, You’ve seen One Microgrid
► Utility Interface Critical
► Carefully Select Utility POI and DER Separation Point(s)
► Understand Electrical Distribution Topology – DER vs. Load
► Plan Blackstart Capability for Unsuccessful Islanding
Question/Answers?
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