



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

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February 11, 2020



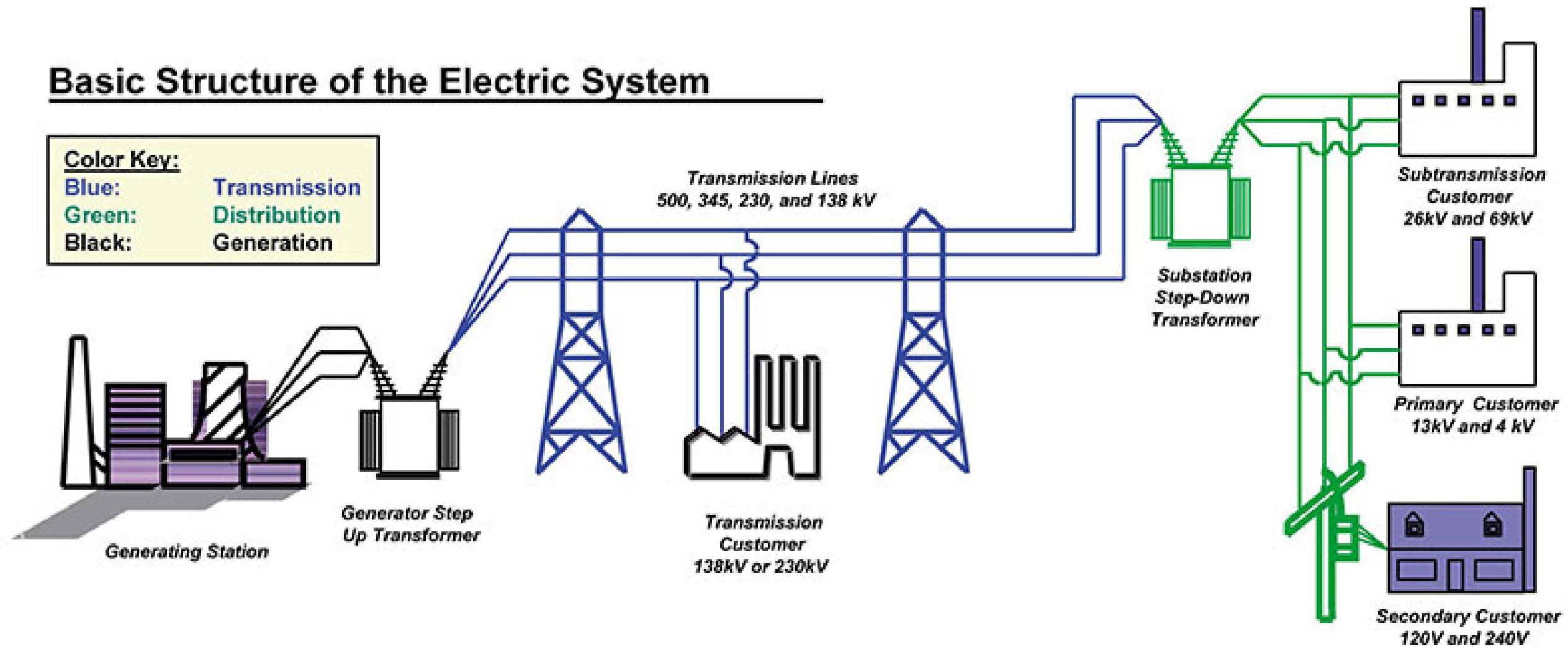
Agenda

- ▶ 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:

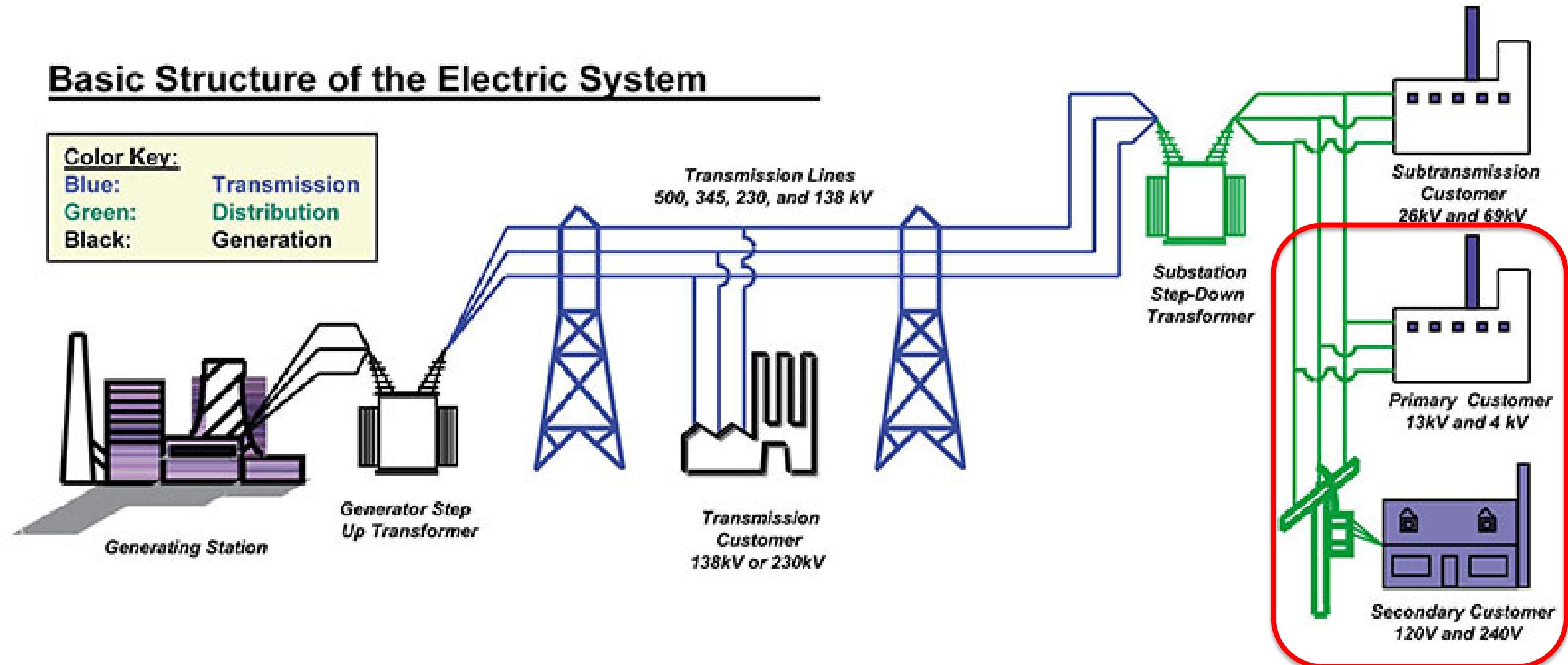
Blue: Transmission
Green: Distribution
Black: Generation



Basic Structure of the Electric System

Color Key:

Blue:	Transmission
Green:	Distribution
Black:	Generation



TYPICAL MICROGRID CUSTOMERS

Interconnection Voltage Level

- ▶ Transmission
 - >69,000V
- ▶ Primary Distribution
 - 12,470V – 34,500V
- ▶ Secondary Distribution
 - 208Y/120V – 4,160V

System Grounding

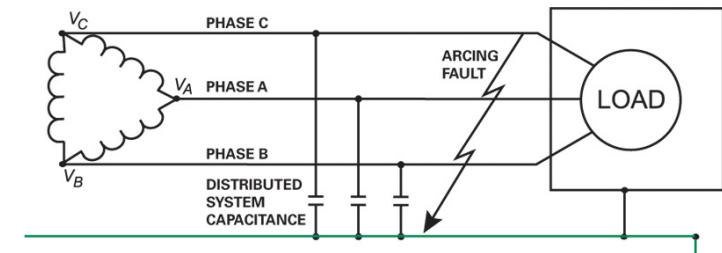
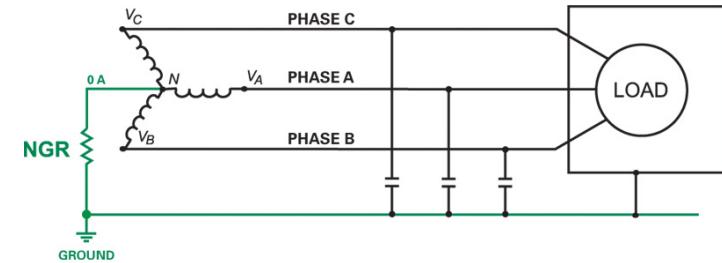
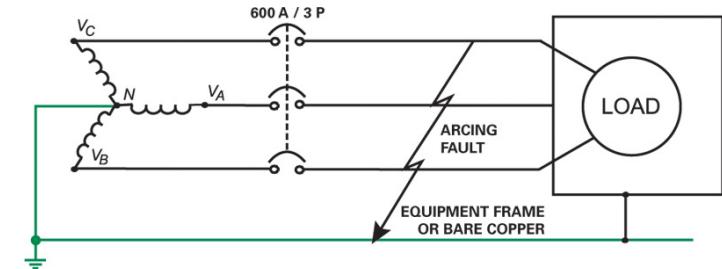
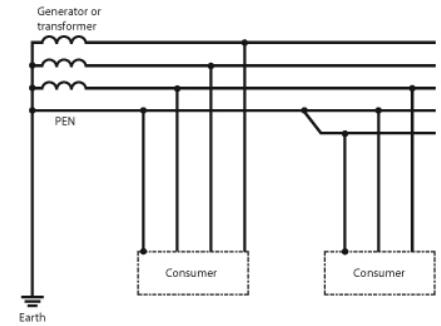
► Utility System

- Typically 3-Phase 4-Wire Multipoint Grounded Wye

► Campus Distribution System

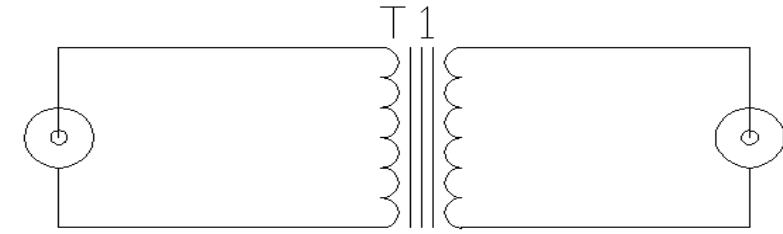
- 3-Phase 3-Wire Solidly Grounded Wye
- 3-Phase 4-Wire Solidly Grounded Wye
- 3-Phase 3-Wire Low Impedance Grounded Wye
- 3-Phase 3-Wire Ungrounded

► Interconnection Transformer(s)?



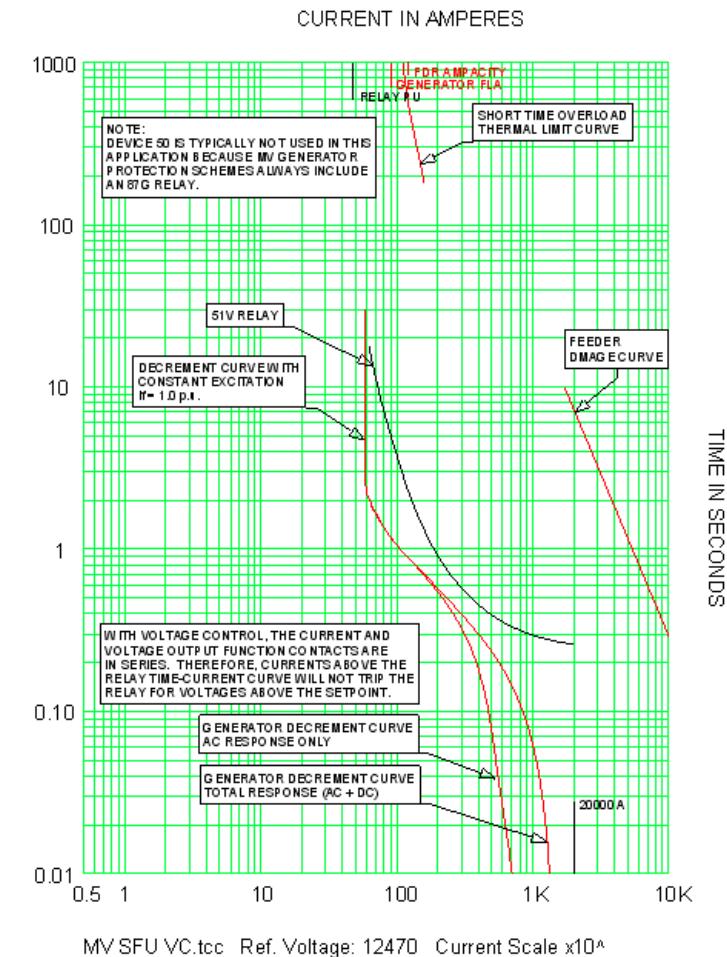
Isolation Transformer at Interconnection

- 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

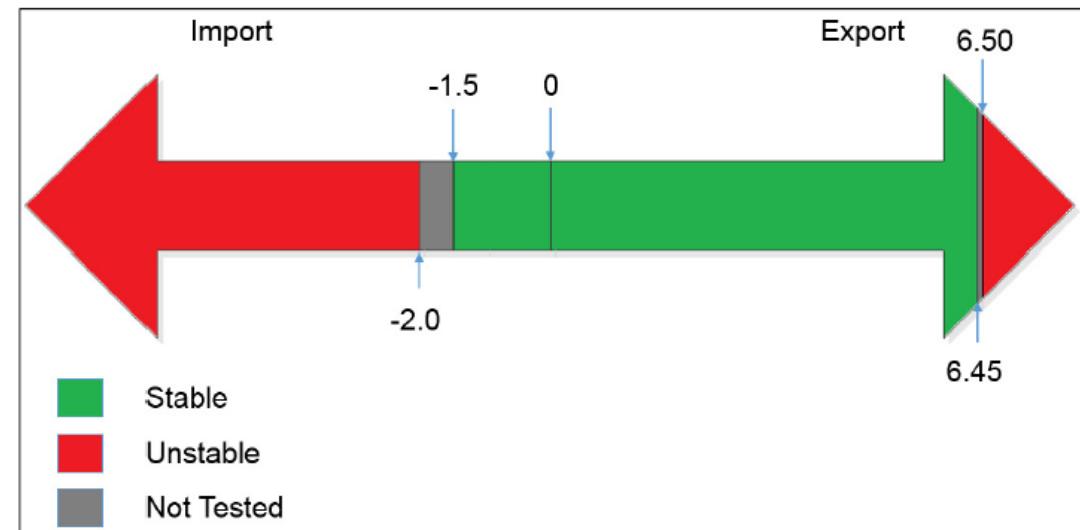
► Additional Protection

- 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



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

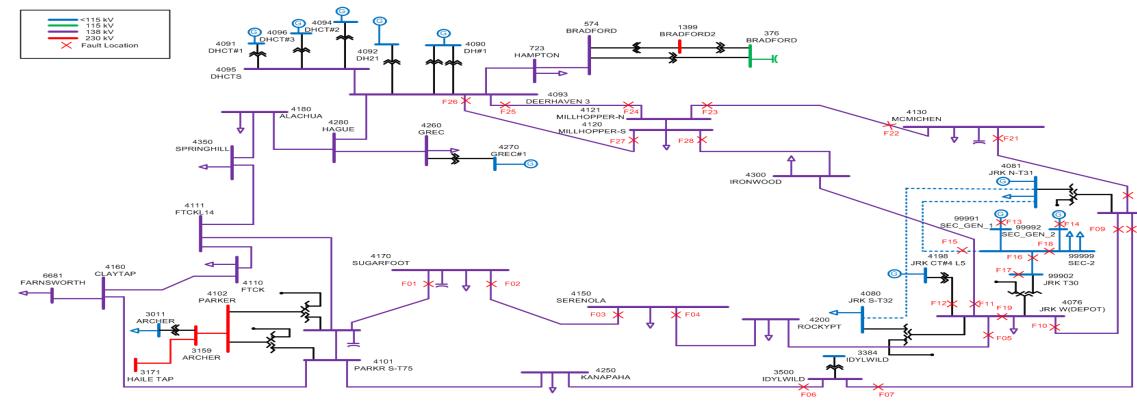
- DER Energize a Portion of the Utility System Following a Utility Outage
- DER Must Automatically Separate from Utility
- Separation Must Occur Before Utility Reclosing

► 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

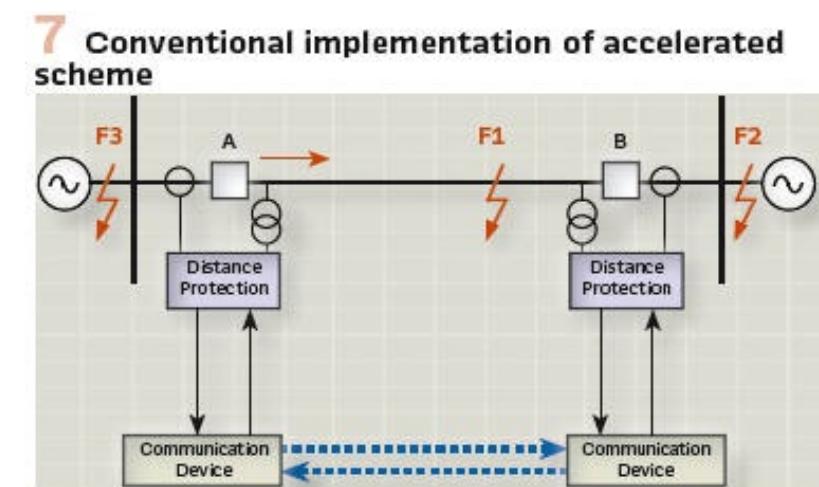
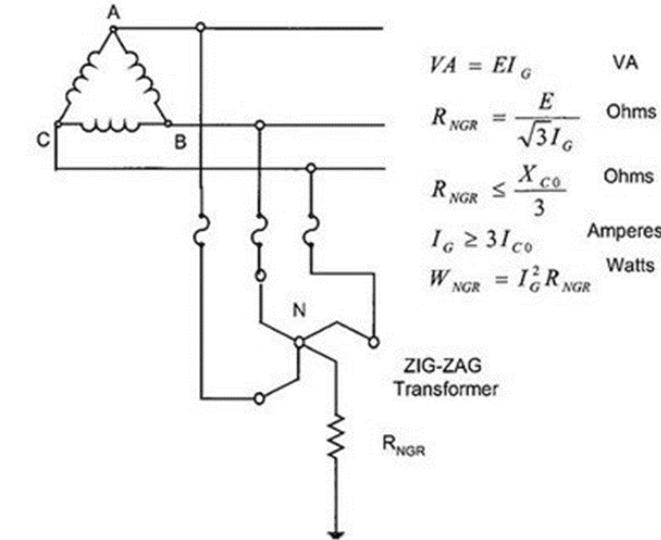
► Ungrounded Island

- 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



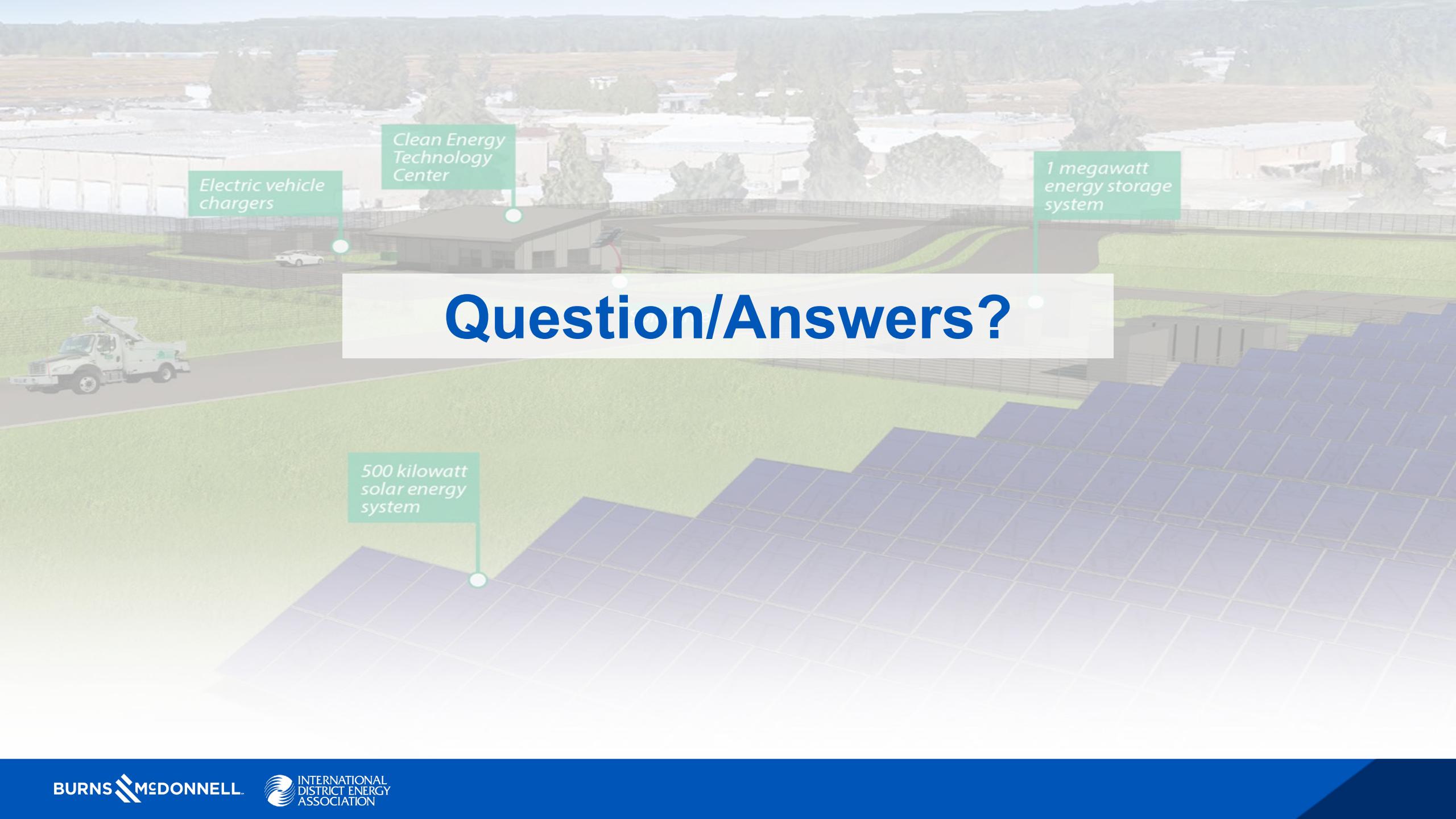
Microgrid Blackstart Parallelizing

- ▶ 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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