Risk of unintentional islanding in the presence of multiple inverters or mixed generation types

presented by:
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Brief introduction to NPPT

• Power engineering consulting firm in Brookings, SD
• Provides engineering, simulation, and design services:
  • EMTP- and PSS/E-type studies and simulation
  • Hardware-in-the-loop testing of relays, controllers and other devices
• Key application areas:
  • Distributed energy resource (DER) interconnections
  • Low-inertia systems (microgrids, emergency/standby power systems, remote community and island grids, off-grid power systems)
Today’s Discussion

• Background on islanding
• Examples of Island Systems
  • Generation by a single manufacturer but numerous inverters
  • Inverters and rotating generation
  • Dissimilar inverters
  • Active vs. passive anti-islanding
• Islanding and grid support functions
• Forward looking solutions
Definition of islanding
When islands can form

• If you have a close generation-load match in real power $P$, voltage doesn’t change much when the island forms

$$P_{load} = V_a \frac{V_a}{R}$$

• If you also have a close match in reactive power $Q$, the frequency doesn’t change much.

$$Q_{load} = V_a \left[ \frac{V_a}{\omega L} - V_a \omega C \right]$$
### Solutions to loss of mains detection (LOMD)

<table>
<thead>
<tr>
<th>Type of method</th>
<th>Description</th>
<th>Effectiveness</th>
<th>Cost</th>
<th>Compatibility with grid support functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive</td>
<td>Monitors terminal voltage for trip condition, but does not adjust inverter output to cause change</td>
<td>Fair to poor, if high speed required</td>
<td>$</td>
<td>Good to excellent</td>
</tr>
<tr>
<td>Active</td>
<td>Actively changes inverter output to cause change, usually uses positive feedback</td>
<td>Excellent in single inverter cases</td>
<td>$$</td>
<td>Poor to very poor</td>
</tr>
<tr>
<td>Communications-based</td>
<td>Relies on communications for system awareness</td>
<td>Excellent (?)</td>
<td>$$$$</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
Quantifying risk of islanding via simulation

• Transient (EMTP-type) simulation is extremely helpful
  • Serves as a “virtual laboratory” for studying the real circuit with real DG
  • Well-vetted over time

• Our procedure:
  • Import feeder data from utility’s GIS database (CYME, Synergi, Milsoft…)
  • Use manufacturer-specific, detailed inverter models
  • Simulate a wide range of loading conditions—start with constant-Z load, but move to ZIP-motor load if necessary
  • Run simulation to find run-on time (ROT) for each loading condition
  • Also allows us to look for transient overvoltage (TOV, GFOV), imbalance issues, and other potential problems
Model building and validation
Anti-islanding with multiple inverters

• In the past, the “multi-inverter case” was seen as a problem
  • Impedance detection could fail in the multi-inverter case
    • Impedance detection involves a current injection—pulse, harmonic, VAr pulse, etc.
    • Then watch for voltage response to that injection
    • If seen, impedance is high; island is indicated
    • For multiple inverters, injections can “average out”
  • Some concern that positive-feedback methods may be desensitized if there are multiple inverters—may “fight” with each other
• But inverters have adapted, and we now have much more experience with large numbers of inverters.
ROT vs. LF and PF, 192 inverters—all same make/model
Islands containing inverters and rotating generation

- Rotating machines and inverters tend to respond in opposite directions
  - Rotating machine stabilizes frequency
  - Inverters and rotating generators tend to move in opposite directions in VArS during transients
- Results show that islands with both inverters and rotating machines can run on, but not always
Inverters and rotating gen: bad case

- Multiple PV plants and large sync gen
- DERs spread across feeder
- Rotating gen is 30% of rated DER on feeder
Inverters and rotating gen: OK case

• Multiple PV plants at approximately same location
• Aggressive positive feedback used by PV
• Rotating gen is 28% of rated DER on feeder
Islands containing dissimilar inverters: Compatible islanding detection

• Four PV plants each with different manufacturers
• Similar positive feedback AI means
• Longer ROT than typical for single manufacturer, but still under 2 seconds
Islands containing dissimilar inverters: Borderline case

- Three PV plants each with different manufacturers
- Combination of positive feedback and impedance detection
- Did exceed 2 sec but no indefinite run-ons
- Voltage imbalance also a factor in this case
Islands containing dissimilar inverters: Incompatible islanding detection

- 2 PV plants with different inverter manufacturers
- Positive feedback on frequency
- Positive feedback on angle separation between phases
Islands containing inverters without positive feedback

• Only passive AI on island
• UL-1741 listed
• All passive AI methods resident in the inverter have a non-detection zone
  • Location is the question
Islanding and grid support functions

• Inverters are increasingly incorporating grid support functions, such as voltage-regulating volt-VAr droops and very permissive voltage and frequency ride-throughs
  • CA Rule 21
  • HI Rule 14H
  • New rules soon to follow in AZ
  • Much of this being adopted into the new revision of IEEE 1547

• Definite concern that traditional active anti-islanding may lose effectiveness with grid support functions.

• How bad is it? Jury is still out.
Forward-looking solutions: what do we want?

• We desire an islanding prevention method that:
  • Reliably detects islands before the first reclose interval
    • Present IEEE 1547 recommendation is 2 s
  • Works for ANY combination of DERs, inverters or technologies
  • Works for ALL locations
  • Will continue to work as the distribution system changes
  • Does not false trip
  • Facilitates a smooth transition into microgrid operation, if desired

• It’s clear that new islanding detection/prevention means are needed—will almost certainly be communications-based, with backup

• Speed, selectivity, sensitivity, and low cost
Direct Transfer Trip (DTT)

• A direct line of communication is used to issue a trip signal to a DER
  • Dedicated phone line
  • Fiber optic
• Well-tested and established technology
• Expensive
  • Cost of communication channel
Power line carrier permissive (PLCP)

- Transmitter injects signal into phase conductors which is read by receivers.
- No practical non-detection zone.
- Can take multiple line cycles to detect island, but higher frequency signal and additional equipment can solve this.
Synchrophasor-based methods

• GPS time stamped phasor measurements at utility and distributed locations are compared

• Variety of algorithms can be used to compare signals

• Longer ROTs possible, but not indefinite
Summary of islanding strategies

- Presence of spinning DG or a mixture of inverter manufacturers can be unpredictable without an in-depth study
- Capacitor banks typically needed to sustain islands
- Ask inverter manufacturers to disclose anti-islanding strategy
  - Passive vs. active
  - Frequency vs. phase
  - Deadband?
- Third-party simulations can be used to determine risk
- The affects of grid-support functions on anti-islanding is unknown so far
  - Volt-Var
  - Frequency-Watt
  - Ride-through
- Cost-effective communication-based methods are desirable
Thank you! Questions?