Updating the Sandia islanding guidelines document

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Topics in this presentation

- Discussion of the “Type System” as a new screening basis
- Learning from recent Sandia-sponsored work on risk posed by cases not covered by IEEE 1547.1 testing
- Learning from recent EPRI-sponsored study on the sensitivity of ROTs to various factors
Necessary condition for sustained islanding

• Real and reactive sources and sinks are such that one can obtain a balance within the prospective island.

• In general, if there is a P imbalance:
  • For GLR < 1, $V$ falls.
  • For GLR > 1, $V$ rises.

• In general, if there is a Q imbalance:
  • For a net-inductive island, $f$ rises.
  • For a net-capacitive island, $f$ falls.
Situations NOT tested by UL-1741 or IEEE 1547.1

• Multiple inverters
• Mixtures of dissimilar inverters
• Mixtures of inverters and rotating machines
• Other than const-Z loads

• Why not?
  • Where does the test matrix stop?
  • Logistical difficulties.
Why islanding is reemerging as a concern

• Much higher DG deployment levels means more of the problem cases.
• Have seen some power quality issues caused by anti-islanding. (Also stability issues in weak grids.)
• Grid support function impacts have raised concerns.
  • RTs
  • V/V, f/W, etc.
• MANY new market entrants, with a wide array of different techniques; some are proven, some are not.
Origins of the real power screen

\[
Z_{\text{load}} = \frac{V_{\text{nom}}^2}{P_{\text{load}}} \rightarrow V_{\text{nom}}^2 = P_{\text{load}}Z_{\text{load}}
\]

\[
V_{\text{isl}}^2 = P_{\text{DER}}Z_{\text{load}}
\]

\[
\frac{V_{\text{isl}}}{V_{\text{nom}}} = \sqrt{\frac{P_{\text{DER}}}{P_{\text{load}}}} \leq 0.88
\]

\[
\frac{P_{\text{DER}}}{P_{\text{load}}} \leq (0.88)^2 = 0.77
\]

From here, 0.67 (2/3) was chosen for margin and simplicity.
Real power screen details

• Assumptions:
  • The inverter acts as a constant-power current source (acceptable assumption after the first few cycles of an island).
  • The 2-s undervoltage trip is at 0.88 pu. (No longer true in the new version of 1547.)

\[
\frac{V_{isl}}{V_{nom}} = \sqrt{\frac{P_{DER}}{P_{load}}} \leq 0.5
\]

\[
\frac{P_{DER}}{P_{load}} \leq (0.5)^2 = 0.25
\]

You can all imagine how popular THIS would be.
Origins of the var screen

• It is possible to derive the following relationship between the island frequency, the EPS frequency, and the var balance in the island*:

\[
\begin{align*}
  f_{isl} &= f_{EPS} \sqrt{\frac{(Q_L + Q_{LG})}{(Q_C + Q_{CG})}} \\
  \frac{Q_{L,isl}}{Q_{C,isl}} &= \left( \frac{f_{isl}}{f_{EPS}} \right)^2
\end{align*}
\]

• For the 60.5 Hz OF trip, the squared quantity = 1.0167. From there, the 1% var match criterion was selected for simplicity and margin.

Var screen details

• Assumptions:
  • The load Q doesn’t change appreciably when the island forms.
  • The inverter vars do not change appreciably during islanding.
  • The closest frequency trip is at 60.5 Hz.

\[
\frac{Q_{L,isl}}{Q_{C,isl}} = \left( \frac{f_{isl}}{f_{EPS}} \right)^2 = \left( \frac{62}{60} \right)^2 = 1.068
\]

So we would now have a ~7% (or more) var matching criterion. This would catch nearly all PV installations.
Working toward the new Sandia screens

• Now completing a new set of Sandia-sponsored work intended to move toward a new version of the Sandia screens. Features:
  • Dispense with the P and Q screens altogether; focus instead on the cases NOT covered by 1547.1 type testing.
  • Simplify data gathering by establishing inverter AI types and quantifying relationships between these.
• Some progress, but some challenges…
New Sandia screens: islanding detection types (W.I.P.)

• **AI Type 1**: fundamental-freq pos-seq perturbation that grows continuously in magnitude as frequency error increases, with no dead zone. (“Pure” SFS and quasi-SFS.)

• **AI Type 2A**: Type 1 but not continuous to the trip limits, except *not* a dead zone.

• **AI Type 2B**: Type 2A, with a dead zone.

• **AI Type 3**: pos-seq perturbation without feedback (Z detection).

• **AI Type 4**: harmonic injection specifically for AI.

• **AI Type 5**: passive AI only.

• **AI Type 6**: negative sequence manipulation.
Challenges

• No more than ten types, but still comprehensive coverage
• Type definitions must be EXTREMELY clear and unambiguous
  • Manufacturers must be able to tell easily which type they are
  • No inverter should fall into more than one type
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Figure 8. Number of loading scenarios in which ROTs exceeded 2 s for each inverter example tested, as a function of the fraction of synchronous generation within the island, without RTs.
Figure 11. Number of loading scenarios in which ROTs exceeded 2 s for each inverter example tested, as a function of the fraction of synchronous generation within the island, with RTs.
Learning so far

• Some representatives of some classes perform significantly better than others in a general sense (SFS and quasi-SFS).
• We definitely DO see degradation when RTs are applied.
• The evidence regarding grid support functions like V/V, f/W etc. is mixed, but so far seems to be a negligible impact on AI overall.
• As a general rule, mixtures of methods do not perform as well as individual methods, but there are exceptions.
• AI becomes more difficult when sync gens are added, in most cases (but not all).
Sensitivity study
Factors being considered

• Irradiance/inverter output power
• Distribution of the load along the circuit
• Distribution of DERs along the circuit
• Phase-phase load imbalance
• Circuit impedance between DERs or loads
• ZP-load Z and P fraction
• Motor load fraction
• Nonlinear load (harmonic current injection level)
AI methods included

• Type 1 (SFS—did best in earlier work)
• Type 3 (Z detection only—did worse in earlier work)
• RoCoF “on”
• Using manufacturer-specific models
Work completed so far (all with RoCoF)

✓ Irradiance/inverter output power
✓ Distribution of the load along the circuit
✓ Distribution of DERs along the circuit
  • Phase-phase load imbalance
✓ Circuit impedance between DERs or loads
  • ZP-load Z and P fraction
✓ Motor load fraction
  • Nonlinear load (harmonic current injection level)
Results so far

- The main result so far is that RoCoF has retained a very high degree of effectiveness, even when Cat II compliant.
- We hope to redo the simulations so far without RoCoF to get a better idea of the sensitivities.
- The main factor that has made a difference so far is the presence of motor load.
Questions?