DER Grounding Practices Survey

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Survey Objectives

- Determine utility grounding requirements for DER
  - Where supplemental grounding is required (MVA thresholds, etc.)
  - How supplemental grounding must be implemented
  - Grounding impedance requirements and limitations
  - Differentiation between synch generators and inverters?
- Assess utility confidence in available analysis tools
- Determine if aggregations of single-phase DER are a concern
- Determine if arrester failures have been observed due to GFOV
- Determine familiarity with IEEE C62.92.6
### Surveyed Utilities

#### NY Utilities
1. Avangrid (NYSEG, RGE)
2. Central Hudson
3. Consolidated Edison
4. National Grid (NY)
5. Orange and Rockland
6. PSEG Long Island

#### Utilities Outside NY
1. AEP
2. Aliant
3. Ameren
4. Centerpoint Energy
5. Dominion Virginia Power
6. Duke Energy
7. Xcel Energy
8. Entergy
9. Exelon (Com Ed, Chicago)
10. Exelon (PECO, Philadelphia))
11. Exelon (PHI, DC, MD, NJ
12. Eversource
13. Hydro One (Ontario, CA)
14. National Grid (MA)
15. Pacific Gas & Electric
Supplemental Grounding Requirements for Inverters

- Majority of surveyed utilities require at least some Inverter-Connected DER to provide a ground source
- Thresholds of requirement range from 50 kVA to 1000 kVA
- Split is about even for utilities requiring/not requiring plants with inverters to provide a ground source
- Approximately one-fourth of the utilities are updating grounding requirements for inverters based on IEEE C62.92.6, considering load contribution to effective grounding.
- A few utilities prohibit DER from providing a ground source
Supplemental Ground Source Implementation

- Of the utilities requiring supplemental grounding, nearly all are flexible and allow:
  - Yg:Yg (MV:LV) with a grounding transformer connected to LV side
  - Yg:Δ; usually with a neutral grounding reactor to limit I₀
  - Δ:Yg (or other LV connections) with a grounding transformer on MV side

- At least one utility specifically allows Yg:Yg:Δ (delta tertiary)
  - Others have not run across this

- None of the surveyed utilities indicated they are prescriptive regarding the configuration of a dedicated grounding transformer
  - i.e., either zig-zag or Yg:Δ
Ground Source Parameterization

- Most utilities requiring supplemental grounding apply it based on DER size and also specify a zero-sequence impedance \( Z_0 \) for grounding.
- There isn’t a standard effective grounding impedance for inverters.
- IEEE C62.92.1-2000 defines effective grounding as:
  - Ratio of \( X_0/X_1 \) is positive and \( \leq 3 \), and \( R_0/X_1 \) is positive and \(<1\)
- Several utilities surveyed use sequence component ratios more appropriate for synchronous machines:
  - For example \( X_0/X_1 = 0.6 \) p.u. and \( X_0/R_0 > 4 \)
- IEEE C62.92.6-2017 addresses grounding and inverter generators
- Approximately 25% of utilities are now considering C62.92.6, updating criteria with symmetrical component analysis
IEEE C 62.92.1-2000    Coefficient of Grounding

Figure 1—Idealized system

\[ C_1 = C_s + C_0 \; ; \quad C_g = 3C_0 \]

\[ X_{C_s} = \frac{1}{\omega C_s} \; ; \quad X_{C_g}/3 = \frac{1}{\omega C_g/3} \; ; \quad X_{C_g} = \frac{1}{\omega C_g} \; ; \quad \omega = 2\pi f \]
IEEE C62.92.1-2000 Earth-Fault Factor

\[
\text{EFF} = \sqrt{3} \frac{\text{COG}}{100}
\]

\[R_s + jX_s\] is the same as seen by all three sequence networks

\[X_{C1} = X_{C2} = \frac{1}{\omega C_s + \omega C_g/3}; \quad X_{C0} = \frac{1}{\omega C_g/3}; \quad \omega = 2\pi f\]

\[
\frac{1}{R_1 + jX_1} = \frac{1}{R_2 + jX_2} = \frac{1}{R_s + jX_s} - \frac{1}{jX_{C1}} = \frac{1}{R_s + jX_s}
\]

\[
R_0 + jX_0 = \frac{1}{(R_s + 3R_n) + j(X_s + 3X_n)} - \frac{1}{jX_{C0}} \approx \frac{1}{(R_s + 3R_n) + j(X_s + 3X_n)}
\]

\[V_f = V_a \times \frac{-jX_{C1}}{R_s + j(X_s - X_{C1})} = V_a\]

where

- \(V_f\) is the Thevenin circuit prefault voltage
- \(V_a\) is the line-to-neutral source of Figure 1
- \(3I_0\) is the fault current through closed switch \(S\) of Figure 1
- \(\approx\) indicates the result when capacitance is negligible
Analysis Tools and Needs

- Short-circuit analysis tools (e.g. Aspen, Cape) are effective for evaluating scenarios with the DER connected to the grid
  - Generally, this situation doesn’t drive the grounding requirements

- Most utilities prefer using these tools for ground fault analysis, however, they are not designed for a critical islanded DER scenario

- Utilities using C62.92.6 calculations are having to using *ad hoc* tools (e.g., spreadsheets, hand calculations)

- Also, cases where aggregations of single-phase DER may pose grounding concerns, symmetrical components analysis don’t work

- There is widespread agreement that better tools are needed
Applying survey results to inform NYSERDA R&D

- GFO scenarios with inverters need to be better defined.
- Inverter zero sequence behavior further characterized
- Analytical methods needed to support application and sizing of grounding transformers for inverter DER
- Considerations for including feeder load contribution to effective grounding needs to be further investigation
- Any new practices and procedures need to be vetted with utility protection engineers
- Webcasts and workshops will enhance technical transfer
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