JOINT UTILITIES
OF NEW YORK

Effective Grounding Interconnection Requirements

May 10, 2018

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Effective Grounding and Interconnection

- Grounding is the method of providing a path of least resistance for electric current to safely return to ground in the event of a fault or surge.

- Utility transmission, sub-transmission and distribution facilities are all designed and built to maintain a specific level or type of grounding. These types include:
  - Effectively Grounded (most common)
  - Impedance/Resistance Grounded
  - Ungrounded (delta or floating wye)

- This presentation applies to effectively grounded systems.

- The same level of grounding effectiveness is required for DG and ESS facilities and utility equipment, in order to not adversely affect the utility's grounding effectiveness.

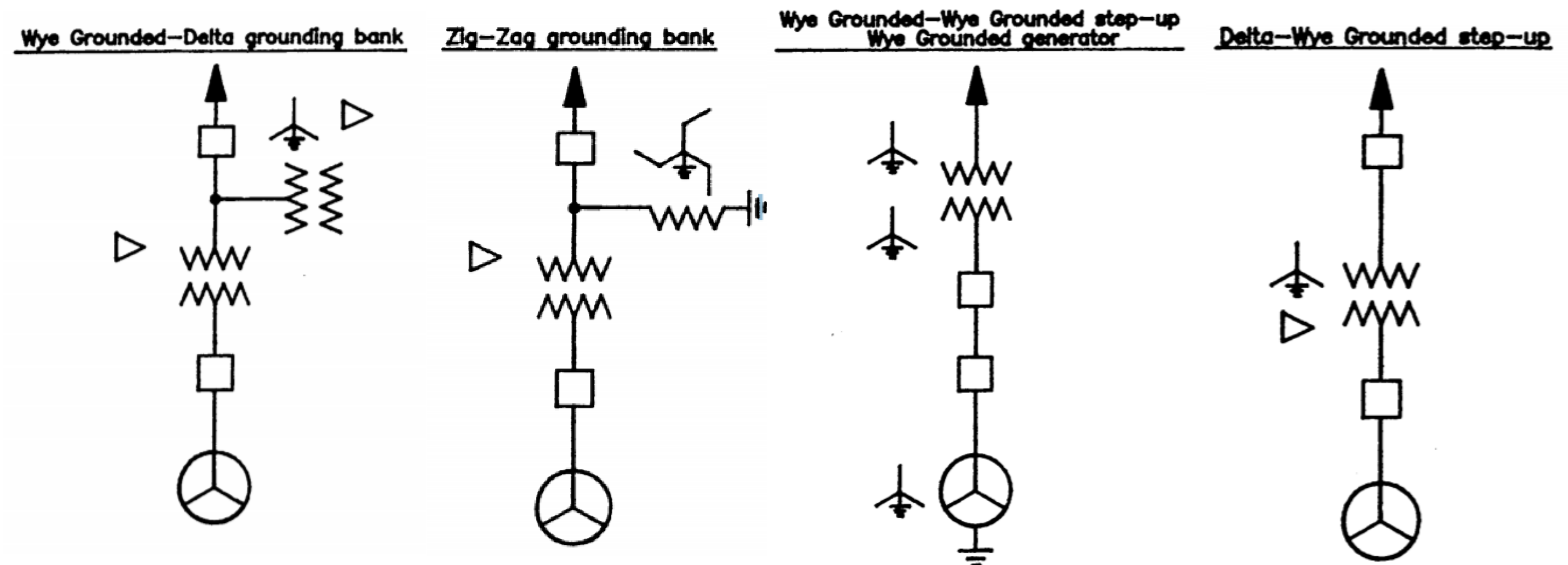
Why is Effective Grounding Important?

- In the event of a phase to ground fault on the Utility system, all phase to ground connected equipment on unfaulted phases will be subjected to overvoltage conditions of up to 173% of the nominal voltage in the absence of effective grounding.
  - This overvoltage condition has the potential to quickly damage both utility and customer owned equipment.
  - This is also public safety concern.
- Effective grounding limits the overvoltage to 125% - 138% of nominal voltages depending on Utility system configurations and requirements.
- An effectively grounded system allows for utility fault protection to operate faster for ground faults by introducing low impedance return paths.

Joint Utilities Approach to Effective Grounding

- While each Utility has its own system design and grounding practices, the Joint Utilities are consistent in collectively requiring effectively grounded DG and ESS facilities.
- Depending on the distribution interconnection transformer configuration, inverter configuration and utility system design, the utility may require one of the following solutions for DER installations on effectively grounded circuits:
  - Requiring or allowing a four-wire grounded generator source be used when connected via a wye-grounded to wye-grounded transformer.
  - A wye-grounded connected primary winding with a fully insulated neutral and the secondary winding to have a delta connection.
    - Note: The insulated neutral allows for the addition of a grounding reactor/resistor in the event the generator's contribution to faults results in undesirable fault current values.
- For all other transformer configurations and/or a ungrounded generator sources, installation of a grounding transformer, such as wye-grounded delta or zig-zag configured transformers located on high or low voltage ratio side of the interconnecting transformer or low side of the utility transformer.

Example Transformer Configurations



The above are examples of transformer configurations providing effective grounding, however this is evaluated on a case-by-case basis per utility and can be subject to change.

Desensitization of Protective Equipment

- Multiple ground sources due to the interconnection of DG and ESS contribute to the reduction of reach of Utility protective devices, resulting in the potential failure to detect and clear a fault.

- In order to not desensitize protective devices, some utilities require that the DG or ESS must limit their fault current contributions or not to be a ground source when not generating . This may be accomplished by:
  - The addition of a properly sized neutral resistor/reactor to the interconnecting transformer or grounding transformer to reduce fault current contributions.
  - Disconnecting the neutral of the grounding bank or high side of the grounding transformer when not generating.

Effective Grounding Benchmarking

- HECO, APS, Xcel Energy, PacifiCorp and Eversource all provide specific grounding transformer requirements to establish effective grounding for inverter based DER interconnections.
  - Other Utilities benchmarked require effective grounding according to compliance with IEEE 1547 in their interconnection requirements.

- Xcel Energy's effective grounding requirements include references to IEEE 1547.2, and note that while these standards can focus on voltage sources such as rotating machines, they still specify that an equivalent effective ground be established for current sources such as inverters for solar PV.

- Other Utilities require a neutral reactor. Rocky Mountain Power of PacifiCorp specifically cites concerns with fault current increases by a value of 10% to ensure protective device desensitization is limited.

Review of Recent Whitepapers and Standards

- The Joint Utilities reviewed the following whitepapers:
  - IEEE Std C62.92.6-2017 - IEEE Guide for Application of Neutral Grounding in Electrical Utility Systems, Part VI--Systems Supplied by Current-Regulated Sources, 2017
  - IEEE Technical Report PES-TR21: System Neutral Grounding Considerations for Inverter-Interfaced Distributed Energy Resource, 2016
  - Solectria Renewables White Paper SRCW00101: Effective Grounding for PV Plants, 2016
  - Advanced Energy: Neutral Connections and Effective Grounding
  - WESC, Reigh Walling: Grounding Transformers in Inverter Applications, 2014
  - NPPT, Mike Ropp: Temporary Overvoltage Issues in Distribution-Connected Photovoltaic Systems and Mitigation Strategies, 2008
  - NREL & SolarCity: Inverter Ground Fault Overvoltage Testing, 2015
  - PacificCorp: Effective Grounding on Customer Generation Facilities, 2018

Conclusions Drawn From Whitepapers and Standards

- Generation to load ratio is an important factor in how quickly an island will be detected and the consequences of an overvoltage.
- The white paper authored by Solectria indicates that a grounding transformer with a wye-grounded to wye-grounded transformer is required when the inverters are not grounded.
- Inverters primarily act as current sources, but not under all conditions. When acting as constant power sources, voltage rise becomes a more significant challenge.
- Without models detailing negative sequence impedances, the results are inconclusive. The paper authored by Advanced Energy also supports additional testing.

Conclusion

- Effective grounding is important to the reliability of the utility system, operation of customer equipment, and public safety.
- Advances in IEEE Standards may influence how inverter-based systems can be effectively grounded.
- Additional lab testing and inverter model information is required to validate model results presented in recent whitepapers.

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Q&A

Thank you!

May 10, 2018

Additional References

- Xcel Energy, 2017
  https://www.xcelenergy.com/staticfiles/xe/Regulatory/Transmission/CO-DG-Tech-Manual.pdf

- PacifiCorp, 2017, Dedicated Transformer and the Need for a Grounding Transformer (Pg. 24)
  https://www.rockymountainpower.net/content/dam/pacificorp/doc/Transmission/Transmission_Services/Generation_Interconnection/Facility_Interconnection_Requirements_for_Distribution.pdf

- Eversource, 2017, Section 2.8 Grounding and Bonding, Page 11:
  https://www.eversource.com/content/docs/default-source/nh---pdfs/der-information-andtechnical-requirements-03242017.pdf?sfvrsn=ab2bfc62_2

- APS, 2016 Section 8.3 Dedicated Transformer, Page 29:
  https://www.aps.com/library/solar%20renewables/InterconnectReq.pdf

- Hawaii, 2018, Rule 14 Section 3.a Design Requirements: Integration with Utility Grounding and Ground System Protection, Revised Sheet No. 34B-12
  https://www.hawaiianelectric.com/Documents/my_account/rates/hawaiian_electric_rules/14.pdf