A2 Power Transformers and Reactors

PS1 – Experience and New Requirements for Transformers for Renewable Generation

Paper ID_216

EFFECTIVE GROUNDING IN MICROGIRDS WITH INVERTER-BASED DISTRIBUTED ENERGY RESOURCES

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Motivation

- Majority of North American electric utility distribution feeders are four-wire multi-grounded systems with neutral conductor being grounded at multiple locations (typically every few poles), with effective grounding being provided by the substation transformer which is typically Δ–Yg or an autotransformer with tertiary Δ winding. Microgrids with inverter-based Distributed Energy Resources (DERs) require effective grounding to be able to operate in islanded mode and this is accomplished by installing the grounding transformer. Current IEEE standards that govern the design of grounding transformers are calculations-based and they are typically used for the power system with synchronous-based generation. As such, these standards are not well-suited for microgrids with inverter based DERs that operate in islanded mode, as they do not provide the optimum grounding transformer design characteristics.

Method/Approach

- This paper presents a new simulation-based grounding transformer design method for microgrids with inverter-based DERs and compares which to calculation-based grounding transformer design methods governed by IEEE Std. C57.32 [1], IEEE Std. C62.92 [2] and IEEE Std. 1547.8 [3] (not approved yet) to validate the proposed design approach

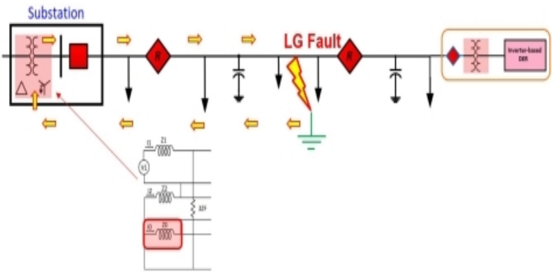

Fig. 1: Substation feeder with DER and ground fault current being cleared by the relay

Objects of investigation

- There are five basic factors that are typically considered when designing the effective grounding scheme for the power system:
- 1.voltage ratings and degree of surge voltage protection available from surge arresters
- 2.limitation of transient line-to-ground over-voltages
- 3.security (relays should not trip when there is no fault on the feeder, to avoid nuisance tripping) and reliability (relays should trip when they detect the fault) of the ground-fault relay protective schemes
- 4.ground fault magnitude current limitation, and
- 5.safety.
- There are two requirements that must be met for the transformer in order for it to provide the effective grounding:
- 1.transformer winding on the voltage level where the ground is required must be connected in Y, where the neutral is connected to the earth, and
- 2." The impedance of the transformer to ground fault current must be significantly lower than the impedance of the connection between the neutral and earth such that this neutral impedance governs the selection grounding mode" [5]. As a result, the only winding on the opposite side of Y that satisfies this requirement is Δ.
- In a traditional power system, effective grounding is provided by the substation transformer, which is traditionally Δ–YG, with Δ winding being on the high side, and YG connection being on the low side or the side where effective grounding is needed. In some cases, autotransformers with tertiary Δ winding are used to provide the effective grounding. Key lesson learned in this case and one of the biggest misconceptions of effective grounding is that simply having the neutral wire connected to the ground on the feeder is not the only requirement for effective grounding.
- Design of effective grounding for microgrids has several major challenges, but two of the most important ones are ground fault currents, and temporary over-voltages (ToV)

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Experimental setup & test results

- The new method for the design of grounding transformer is simulation-based iterative process. In order to successfully perform the analysis, it is necessary to know some of the technical characteristics of few grounding transformers that are potential candidates in order to find the optimum solution.
- 1.Construction type: similar to before, grounding transformer construction is YG-Δ.
- 2.Primary and secondary voltage: also similar to before, primary and secondary voltages for grounding transformer are chosen to be 12.47kV – 480V
- 3.Impedance Z0 and Neutral fault current withstand rating:

This step represents the major difference between the existing standard and new method being proposed in this article. The impact of grounding transformer zero-sequence impedance Z0 is two-fold:

- a.Z0 only has impact on ground fault currents (LG and LLG)
- b.higher Z0 impedance results in lower ground fault currents
- c.higher Z0 at the same time results in higher voltages on unfaulted phases during the ground fault, therefore resulting in higher CoG.

Discussion

Implementation of proper DER transformer configuration within microgrid and design and implementation of grounding transformer present very complex engineering endeavor. This paper introduced the new methodology for designing the grounding transformer within the microgrid with inverter based DERs. The main conclusion is that the new proposed approach provides optimum grounding transformer design characteristics for microgrids with inverter-based DERs operating in islanded mode compared to the current standards-based approaches, and that the existing approach would result in grounding transformer design which would fail under steady-state conditions and result in either high ToV or not effectively grounded system. Additional challenge with improper design of grounding transformer is the energization in islanded mode, due to the inrush current, which could easily result in microgrid blackout. In addition, due to the low fault currents, it would not be possible to design secure and reliable protection and control scheme using the current standards-based approach

TABLE V: Grounding transformer characteristics - comparison

Design parameter	IEEE C62.92	New Method
Construction	Y_G-Δ	
Voltage	12.47kV – 480V	
Impedance	$Z_0 = 67.05\Omega$	$Z_0 = 2.90\Omega$
Neutral current steady-state rating	3.23A	10.94A
Neutral current fault withstand rating	107.65A	159A
Time	10-second	1-minute
kVA rating	775kVA	1144 MVA

Conclusion

- Because of all challenges that the design of effective grounding presents when it comes to microgrids with inverter-based DERs, the conclusion of this paper is that it is necessary to form a Working Group within CIGRE that would work on issuing a new standard for the design of grounding transformer for microgrids operating in islanded mode with prevalence of inverter-based DERs.