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Staying Grounded:
Grounding Transformers vs. High-Speed Ground Switches

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BACKGROUND

Medium voltage systems in wind power plants are typically grounded at the main power transformer in the collector substation. When a collector circuit is disconnected from the substation during a ground fault, the ground reference is lost, but the wind turbines will continue to feed the fault. This situation can expose collection system to damaging **Transient Overvoltages** (TOVs).

Transient Overvoltages stress equipment insulation and can lead to failure of surge arresters and other equipment throughout the collection system. This can be avoided by ensuring the collector feeders are **Effectively Grounded.**

A system is considered effectively grounded when the highest voltage seen on an unfaulted phase during a line-to-ground fault is less than 80% of the line-to-line voltage. This can be represented as:

$$.8 > V_{LG}/V_{LL}$$

There are two methods commonly used throughout the wind industry to ensure collection systems are effectively grounded:

1. **Grounding transformers, and**
2. **High-speed grounding switches**

OBJECTIVES

This presentation:

1. Defines effective grounding and discusses consequences of poor design.
2. Provides background on grounding transformers and how they are used.
3. Provides background on high-speed grounding switches and how they are used.
4. Discusses pros and cons of both mitigation strategies.

GROUNDING TRANSFORMERS

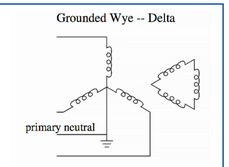
- *Provides ground reference through transformer winding connections*
- *Well-known design, default for many engineers. More widely used*
- *Require calculations to size correctly*

Pros:
- Passive Device
- Familiar to O&M Staff
- Proven Reliability

Cons:
- More Expensive / Additional Equipment
- Power Losses throughout Life
- Complicates Relay Protection
- Additional Space is required
- Increases Ground Fault Current

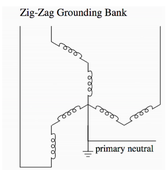
Delta-Wye

- ***Off-the-shelf (shorter lead time)***
- ***Can power aux. load***
- ***More common in North America***

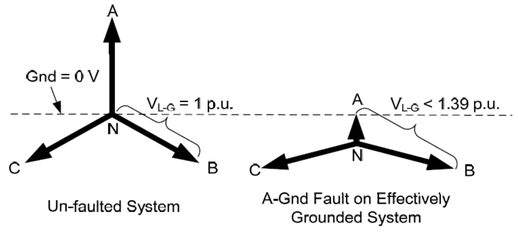


Zig-Zag

- ***Small kVA rating / footprint***
- ***Specialty order, can have longer lead time and be more expensive***

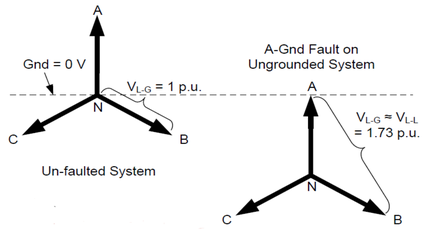


EFFECTIVELY GROUNDED



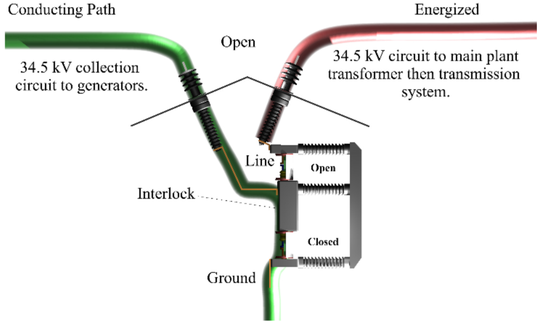
VS.

EFFECTIVELY UNGROUNDED



HIGH-SPEED GROUND SWITCHES

- *Provides ground source by solidly grounding feeder after breaker opens ("break-before-make")*
- *Typically grounds feeder 12-16 ms after opening (<1 cycle)*
- *Mechanical interlock is utilized (can be electrically actuated, but not commonly used due to reliability concerns)*
- *Forces crowbar engagement for type 3 WTGs*



Pros:
- Less equipment required / cheaper
- No losses throughout plant life
- Reduces Arc-Flash Energy
- Simpler relay settings and insulation coordination
- Better performance for limiting TOVs
- Additional flexibility in special operating conditions (can effectively ground multiple feeders)

Cons:
- Doesn't provide passive grounding (reliability?)
- Shorter history of operation/use
- Less commonly used/less familiarity
- Exposes turbines to 3-phase faults
- Limited Suppliers

CONCLUSIONS

- Effective grounding of your collection system is a critical consideration for your wind farm design.
- The two common solutions to avoid transient overvoltages are grounding transformers and high speed grounded switches.
- Grounding transformers and high-speed grounding switches have different design considerations and costs that need to be weighed to ensure an optimal design for your wind farm.

BIOGRAPHY

Brian Connaghan is a Senior Consultant with Sargent & Lundy. He provides a variety of consulting engineering services, including renewable energy due diligence, construction monitoring, financial reviews, and operation assessments. He has performed independent engineering evaluations of various wind energy portfolios, including reviews of project financial projections, budget reviews, contract reviews, and independent design reviews. He has also prepared reviews of plant design, operating performance, O&M, contracts and agreements, and the financial overview of various power projects. He holds a B.S. in Electrical Engineering from the University of Illinois at Urbana-Champaign and he is a licensed Professional Engineer in Illinois.

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ABOUT SARGENT & LUNDY

As part of our more than 125 years of electric power industry experience, Sargent & Lundy has significant wind energy experience. We provide a full range of services to the wind industry, including site screenings, project feasibility studies, wind resource assessments, independent engineering, interconnection planning, conceptual engineering, contract development, detailed engineering, design reviews, construction monitoring, commissioning services, and O&M support.