Assessment of Various Technologies Influence to Reduce the Impact of Single-Phase Earth Faults in Distribution Systems with an Isolated Neutral

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Introduction

- Single line to ground (SLG) faults are the most common type of faults in power distribution systems, accounting for approximately 70% of all faults.
- To mitigate the risks associated with SLG faults, an Arc Suppression Device (ASD) is used.
- The ASD is typically installed in the neutral point of the distribution system transformers to reduce the fault current.
- There are two types of ASD: passive and active.
  - Passive ASD: uses the passive elements to be installed on the neutral point of the distribution system transformers to suppress the fault current.
  - Active ASD: Also installed in the neutral of the distribution system transformers, it actively suppresses the fault current using voltage injection.

Main Contributions

- To introduce an analytical comparison between the Peterson coil and the Active Arc Suppression Device (AASD);
- This proposed AASD uses the zero sequence component injection in the neutral point to suppress the fault current.
- And then we have the ability to explore the intricate dynamics of different grounding mechanisms and their impact on system behavior.

Agenda

3. Peterson Coil
4. Arc Suppression Device
5. Case Study
6. Results and Discussions
7. Conclusions

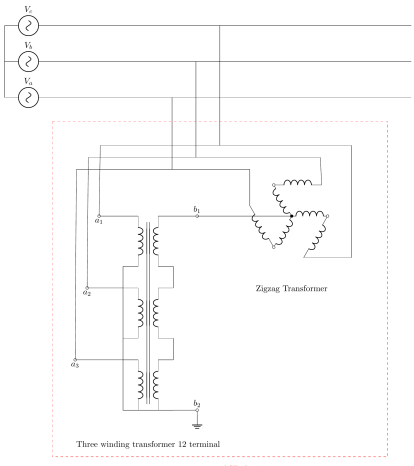
Peterson Coil

- Peterson coil neutralizes line capacitance, especially in high-capacitance transmission lines.
- Key functions:
  1. Compensates for capacitor charging current.
  2. Neutralizes line capacitance.
  3. Maintains stable neutral point voltage.
- Variable inductance: $L = \frac{1}{\omega^2 C}$.

Example: For C_{606} and 50 Hz, coil inductance is 1.0574 H.

Arc Suppression Device I

- The power industry employs symmetrical components for the analysis of unbalanced three-phase systems. The zero sequence component plays a pivotal role in fault detection and diagnosis.
- An innovative device is proposed that uses the zero sequence component for the suppression of SLG faults.
- The device is comprised of two parts: a zigzag transformer and a three-phase transformer.
- The device combines features of both active and passive arc suppression techniques.



Arc Suppression Device II

The function of each part of the device consists of:

- Zigzag transformer for cases without a real ground point or ungrounded systems.
- Three-phase transformer designed to extract the zero voltage component.

For the three-phase transformer, the voltage is calculated according to the following equation:

$$v_{\text{open}\Delta} = v_a + v_b + v_c = 3v_o \tag{1}$$

The zero sequence voltage is calculated according to the following equation:

$$v_0 = \frac{1}{3}(v_a + v_b + v_c) \tag{2}$$

Arc Suppression Device III

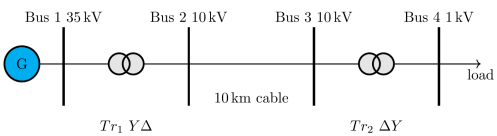
For the zigzag transformer, the neutral point is calculated according to the following equation:

$$v_{n\ \text{zigzag}} \begin{cases} I_g * 3 * Z_{zigzag} & \text{Case 1} \\ v_{\text{open}\Delta} & \text{Case 2} \end{cases} \tag{3}$$

The two cases are: if the system's neutral point is connected to the ground (Case 1) or if the neutral point is connected to the open delta (Case 2).

System Overview

- Source feeds first bus (35 kV), star-delta transformer 35/10 kV, and cable.
- Second bus connected to transformer's secondary side and beginning of the cable.
- Third bus as primary side of delta-star transformer and the end of the cable, the transformer is steps down voltage to 1 kV and connects to fourth bus.
- Fourth bus connected to load.



10 km Cable Parameters Configuration 606

R (Ω/km):

	Phase A	Phase B	Phase C
Phase A	0.4960	0.1983	0.1770
Phase B	0.1983	0.4903	0.1983
Phase C	0.1770	0.1983	0.4960

L (H/km):

	Phase A	Phase B	Phase C
Phase A	0.7356	0.0541	0.0236
Phase B	0.0541	0.6661	0.0541
Phase C	0.0236	0.0541	0.7356

C (F/km):

	Phase A	Phase B	Phase C
Phase A	0.3194	1.3063e-6	1.3063e-6
Phase B	1.3063e-6	0.3194	1.3063e-6
Phase C	1.3063e-6	1.3063e-6	0.3194

Transformers Data

	Transformer 1 $Y\Delta$:
Nominal power and frequency	[10e6 VA, 50 Hz]
Winding 1 parameters	[35,000 V Ph-Ph, 0.245 Ω, 0.031194 H]
Winding 2 parameters	[10,000 V Ph-Ph, 0.06 Ω, 0.0076394 H]
Magnetization resistance	61,250 Ω
Magnetization inductance	194.96 H

	Transformer 2 ΔY:
Nominal power and frequency	[10e6 VA, 50 Hz]
Winding 1 parameters	[10,000 V Ph-Ph, 0.06 Ω, 0.0076394 H]
Winding 2 parameters	[1,000 V Ph-Ph, 0.0002 Ω, 2.5465e-05 H]
Magnetization resistance	15,000 Ω
Magnetization inductance	47.746 H

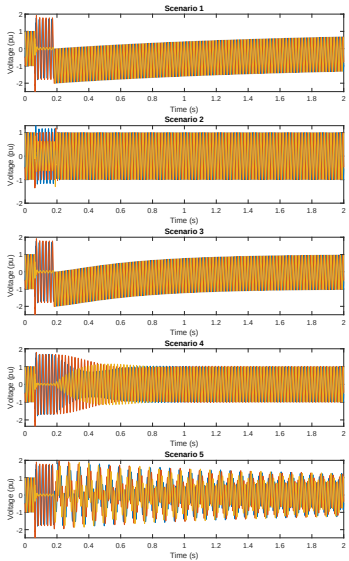
Load Parameters

	Phase A	Phase B	Phase C
Active power (kW)	485	485	485
Reactive power (kvar)	190	190	190

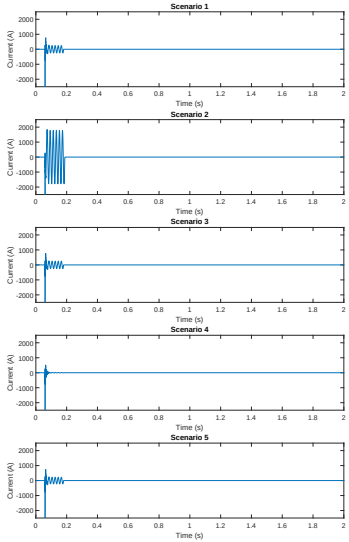
Operational Scenarios

Scenario No	Description
1	Reference case: Absence of any supplemental grounding mechanism.
2	Implementation of a zigzag transformer for grounding purposes.
3	Introduction of an Active Arc Suppression Device (AASD) for grounding.
4	Application of a Peterson coil featuring an inductance lower than resonance value (0.1).
5	Deployment of a Peterson coil with inductance equal to the resonance inductance.

- Three Phases Voltage at Bus 2:
  - AASD system recovers faster than ungrounded system, but still has longer recovery time.
  - Peterson coil recovers instantly in terms of voltage, but voltage remains unstable.
- Performance of lower inductance is better than higher inductance due to resonance effect.

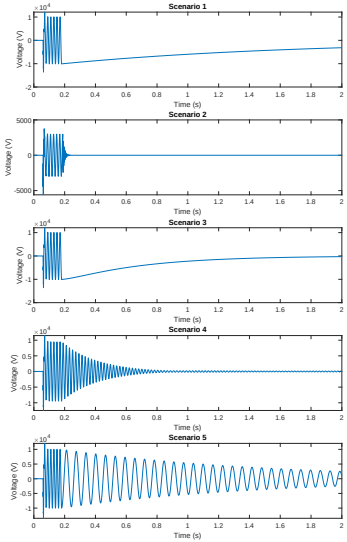


- SLG fault Current occurs at Phase c in the middle of the cable.
- Using any grounding mechanism reduces the SLG fault current compared to a grounded system, indicating the success of the AASD and Peterson coil in mitigating the SLG fault current.

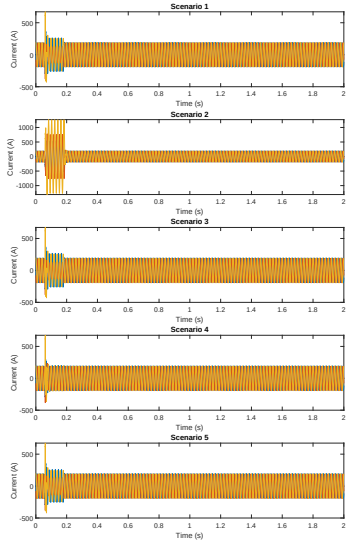


This figure shows the zero sequence component of the voltage at the beginning of the cable.

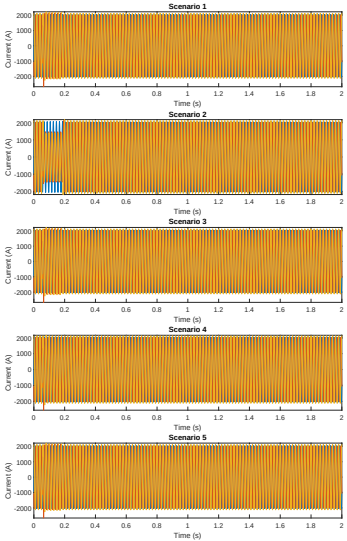
- Zero sequence component is not favorable for DS.
- AASD and Peterson coil with lower inductance take the same time to eliminate, but with more stable behavior.
- Grounding mechanism is faster than the ungrounded system.



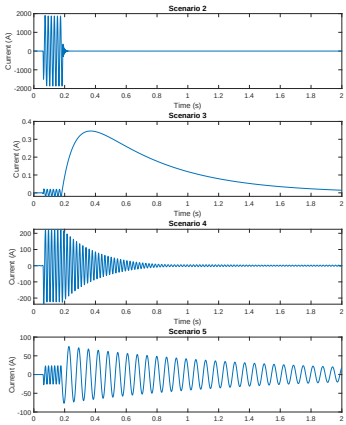
- Three Phases Current at Bus 2:
  - Grounded system's load current is high in healthy phases due to feeding the fault from the delta side of transformers.
  - Scenarios with AASD and Peterson coil do not exhibit this behavior.



- Three Phase current for the load bus:
  - Grounding devices maintain good power quality, similar to the ungrounded system.
- Load current behavior: Stability maintained across scenarios, favorable power quality in most scenarios due to delta transformers.



- Ground Current for all scenarios except Scenario 1.
- Peterson coil generates high currents, AASD eliminates ground current but complicates fault detection.



Conclusions

- This research investigated the impact of various grounding strategies, including the use of a Peterson coil and an AASD, on a four-bus power system.
- The Peterson coil was found to be effective in mitigating single line-to-ground faults in cables connecting delta-side transformers, however, high inductance levels can lead to unstable neutral voltages.
- The introduction of an AASD provided quick response times, even outperforming the base case in scenarios with elevated transmission line capacitance.
- The analysis highlighted the complexities in fault detection when ground currents are eliminated, indicating the need for advanced techniques such as Neural Networks.
- The strategic use of grounding mechanisms is crucial for maintaining the stability and reliability of modern power systems, ensuring efficient and uninterrupted power supply.

Thank you!

Ready for questions.

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