Protect-DG
Uudet tekniikat sähköverkon vikatilanteiden ja hajautetun tuotannon hallinnassa

Amir Farughian

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Overview

- Single-phase earth fault location
  - Review of the existing methods
  - Improving a method
    - Sequence currents
    - PSCAD simulations
    - Theoretical analysis
  - Earth fault location based on signaling
  - Intermittent earth fault

- Publications and reports
Fault location methods

Centralized Methods
- Impedance based
- Artificial intelligence
- Travelling waves

Distributed Methods
- Basic Electrical Quantities
  - Relays
  - Fault Passage Indicators
  - Smart Meters
- Signalling
  - Pulse
  - Non-grid frequency
Fault location methods

Centralized Methods
- Impedance based
- Artificial intelligence
- Travelling waves

Distributed Methods
- Basic Electrical Quantities
- Relays
- Signalling
  - Pulse
  - Non-grid frequency
- Fault Passage Indicators
- Smart Meters
Impedance-based methods not promising!


“Commercial solutions for computational location of single-phase earth faults is not yet available, regardless of the research and development work done in recent years [1]. Due to lack of solutions for computational fault location of earth faults, application of Fault Passage Indicators (FPIs) is a promising alternative [2].”

But now we have smart grids:

• Good sensors
• Working communication
• IEDs with high sampling rate, etc
Fault location using sequence components
Basic method


Along the fault current path between the feeding substation and the fault point, the **negative sequence component** varies only a little but it is practically non-existent behind the fault.

Negative sequence component
Negative sequence component (current)

- Negative sequence current can be obtained from phase currents

\[ I_{\text{neg}} = \frac{1}{3} (I_a + aI_b + a^2 I_c) \]
\[ a = -\frac{1}{2} + j \frac{\sqrt{3}}{2} \]
PSCAD simulations

• Rural
  – Isolated
  – Compensated

• Urban
  – Isolated
  – Compensated
Some PSCAD simulation results of the basic method (Lehtonen)
Primary transformer

<table>
<thead>
<tr>
<th>Healthy feeder</th>
<th>Background network</th>
</tr>
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<tbody>
<tr>
<td>AHXAMK 5 km</td>
<td>AL132 20 km</td>
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<td>Pigeon 35 km</td>
<td>Raven 50 km</td>
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Primary transformer

Background network

AHXAMK 5 km

AL132 20 km

Pigeon 35 km

Raven 50 km
Background network

Healthy feeder

Primary transformer

AHXAMK  5 km  AL132  20 km  Pigeon  35 km  Raven  50 km

0 A  0 A  0 A  0 A  0 A  0 A
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Background network

Healthy feeder

Primary transformer

AHXAMK 5 km AL132 20 km Pigeon 35 km Raven 50 km

Background network

Primary transformer

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Primary transformer

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Rf (Ω)

0.01 44.17 A

44.13 A 44.21 A

6.24 A 3.07 A
Primary transformer

Healthy feeder

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AHXAMK
5 km

AL132
20 km

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Rf (Ω)

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44.17 A
44.13 A
44.21 A
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1
44.05 A
44.02 A
44.09 A
6.22 A
3.06 A
Background network

Primary transformer

Healthy feeder

AHXAMK  AL132  Pigeon  Raven

5 km  20 km  35 km  50 km

Rf (Ω)

0.01  44.17 A  44.13 A  44.21 A  6.24 A  3.07 A
1   44.05 A  44.02 A  44.09 A  6.22 A  3.06 A
10  42.66 A  42.63 A  42.70 A  6.02 A  2.96 A
100 23.20 A  23.18 A  23.22 A  3.27 A  1.61 A
Primary transformer

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Background network

Healthy feeder

Primary transformer

- AHXAMK
- AL132
- Pigeon
- Raven

Rf (Ω)

- 0.01: 44.17 A, 44.13 A, 44.21 A, 6.24 A, 3.07 A
- 1: 44.05 A, 44.02 A, 44.09 A, 6.22 A, 3.06 A
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- 100: 23.20 A, 23.18 A, 23.22 A, 3.27 A, 1.61 A
- 1000: 2.99 A, 2.98 A, 2.99 A, 0.42 A, 0.20 A
- 3000: 1 A, 1 A, 1 A, 0.14 A, 0.06 A
Improved method

• Invention disclosure
  – Addresses the shortcoming of the basic method

• Report
  – theoretical analysis
  – PSCAD simulations
Main advantages of the new method

• Cost-effective
  ▪ No need for voltage measurement. It is based on only current measurements that can be performed by Rogowski coil
  ▪ Compared to signal injection methods, there is no need for additional injection devices

• Independent of the fault resistance
Basic method

- The basic method is in use already in urban networks. Its performance is good as in urban networks the fault resistance is close to zero ohms.
Fault location based on signaling
Principles of the method

Intermittent Earth Fault
Intermittent earth fault location _ possible solution

Faulted phase currents before and after the fault point
Publications and reports


- Invention disclosure (waiting for a decision)


- Sampo Voima, Amir Farughian, “Intermittent Earth Fault Protection and Location”, June 2017 (report)