ACTIVE EARTHING SYSTEM FOR MV NETWORKS BY MEANS OF POWER ELECTRONICS

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MV Earthing

• MV and HV basic criteria
  – Person and system safety
    • Touch and step voltages
    • Fault current limit
    • Required insulation level
  – Network protection system
    • Relaying
  – Power Quality
    • Reliability of supply
    • Voltage dip/swell

• Not uniform criteria
Most common...

Low impedance

Solid
Cable

Reactors
Resistor
Zig-zag

Compensated

Arc suppression coil

... or Isolated System.
# State of the Art

<table>
<thead>
<tr>
<th>Earthing System</th>
<th>Voltage dips</th>
<th>Interruptions</th>
<th>Material stress due to</th>
<th>Protection</th>
<th>Suitability for large underground networks</th>
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<tbody>
<tr>
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- Good
- Fair
- Poor or requires complex systems

- **System response to faults**
  - Depends on fault and earthing impedance
  - Cannot be modified by user
- **Drawbacks in some features**
Zero sequence equivalent

\[ I_N = -3\cdot I_C + I_{\text{Asymmetry}} \]

\[ V_N = 3\cdot I_C \cdot Z_{3C} \]

\[ Z_0 = Z_{3C} / Z_{\text{Asymmetry}} \]
Active Earthing: Goal

- Control phase-to-earth voltages
  - Controlled neutral current injection
  - Controlled neutral to earth voltage
- Phase-to-phase voltages remain unchanged

\[
\begin{align*}
\overline{V}_N &= \overline{I}_N \cdot \overline{Z}_N = \overline{V}_0 = \overline{I}_0 \cdot \overline{Z}_0 \\
\overline{V}_{\text{phase-to-earth}} &= \overline{V}_{\text{phase-to-neutral}} + \overline{V}_N
\end{align*}
\]
System Topology

- Combination of
  - Protective relay
  - System control
  - Fault detection
  - Measurements
  - Power electronics
    - 50 Hz current to change $V_N$
    - Other frequencies for fault location
Earth-fault detection

- Zero sequence voltage measurement
  - $|V_0| > |V_{\text{threshold}}|

- X/R change
  - $(X/R)_{\text{measured}} < (X/R)_{\text{no\_fault}}$
Fault extinction

• **Target:**
  – $V$ faulted phase = 0 $\implies$ Fault current $\approx 0A$

• **Risk:**
  – Overvoltage in sound phases
Fault location

• Frequency ≠ 50 Hz
  – Accurate measurements.
  – Less influence of load current
  – Different change of impedance in faulted feeder
  – Improves distance to fault measurement
Predictive Maintenance

- Controlled undervoltage
  - Prevent insulation failure
- Controlled overvoltage
  - Provoke leakage
  - Check insulation: cables, surge arresters…

\[
\text{Phase-to-earth voltages} + \text{Neutral-to-earth voltage} = \text{Resulting phase-to-earth voltages}
\]
# Active vs. Passive

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- **Good**: Green
- **Fair**: Grey
- **Poor or requires complex systems**: Red
Improved Power Quality

• Payback for active earthing
  – Fault extinction
    • Voltage dip number reduction
    • Lower system stress levels
  – Fault location
    • Statistics based corrective maintenance
  – Predictive Maintenance
    • Insulation replacement
    • Tree trimming…
Step 1: Validation on a scale model
Step 2: Field Installation

- Gernika 30/13.2 kV, 10 MVA substation
Thank you very much!

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