Summary of the Impacts of Grounding on System Protection

Grounding

- System grounding big impact on ability to detect ground faults
- Common ground options:
  - Isolated ground (ungrounded)
  - High impedance ground
  - Low impedance ground
  - Solid or effective ground
## Purposes of Grounding: National Electrical Code

- Personal Safety (injury, fire…)
- Ensure Operation of Protective Devices
- Noise Control (esp. at high frequency)

## Ground Fault Protection

- Roughly 80% of faults on T&D systems are SLG (single line to ground)
- Ground faults can cause:
  - Large, damaging or dangerous currents
  - EMI problems
  - Voltage sags and interruptions (tripping)
  - Voltage stresses
Issues with Ungrounded Systems

- No intentional ground on neutral/ phases
- Ground fault causes neutral shift

\[
\begin{align*}
V_{an} &= V_{ag} \\
V_{bn} &= V_{bg} \\
V_{cn} &= V_{cg} \\
G &= \:\Rightarrow \:\text{Neutral} \\
V_{an} &= -V_{ng} \\
V_{ab} &= V_{bg} \\
V_{ca} &= V_{cg} \\
V_{ab} &= V_{bg} \\
V_{ah} &= V_{hg}
\end{align*}
\]

- Need L-L voltage rating on insulation

Ungrounded Systems

- Parasitic capacitance in all components
- Resonates with line inductance, often doubles transients over voltage
- Equipment damage may result from voltage, but not likely from fault currents unless a second ground fault occurs
Ungrounded Protection Characteristics

- Low fault currents, some self-extinction
- Poor relay relay response and direction
- Often protect based on voltage
  - Zero sequence or three phase voltage
  - Or loss of injected signal
  - Or capacitive currents in cables
- Detect first ground fault and alarm, since second ground fault has big current

High Impedance Ground: Resistive Type

- Large resistance connected to neutral
- Common in large generator protection (sometimes transformer in neutral)
- Size resistance to limit fault current to 25A or less
- Neutral voltage shifts, over voltage relay connected across resistor
- Poor directional capability
### High Impedance Ground: Peterson Coil

- Normal unbalanced operation on distribution line poses problems
- Still need line to line rating on insulation

### Impedance Ground

- **Resistance Ground**
  - High R: \( I_f < 10 \text{ A} \)
  - Low R: \( 10 \text{A} < I_f < 1000 \text{A} \)
- **Inductive Ground**
  - Zig-zag transformer
  - Poor performance in general
- **Resonant Ground** (ground fault neutralizer)
Low Impedance Ground:

- Limit fault current to 50-600 A
- Current sensing used for relaying and can do direction sensing
- Limit over voltages nearly as well as effective ground
- Sometimes use zig-zag transformer with resistor on neutral (if no R, then magnetizing branch is ground path)

Solid Effective Grounding

- Most popular in North America
- $X_0/X_1 \leq 3$ and $R_0/X_1 \leq 1$ and are positive
- Uni-grounded (Europe) versus multi-grounded (U.S.)
- Best for detecting faults, sensing direction, and fault locating
Solid Ground

- No intentional added impedance
- Ground neutral on WYE
- Ground one corner of $\Delta$
  - Overvoltages $< 1.73 \times V_{in}$ in general
  - Good for fault locating

Earth Electrode

- Impedance:
  - Electrode itself
  - Electrode to earth resistance
  - Earth Resistance
  - Keep very small or
  - Match characteristic impedance of conductors (minimize reflections of fast transients)
  - Keep relatively constant to 50th harmonic
References

- National Electrical Code
- IEEE Green Book