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

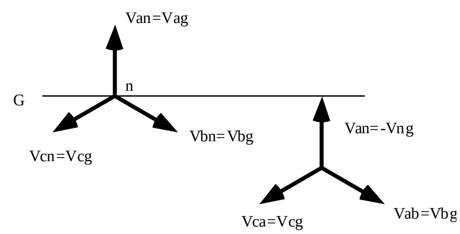
- Personal Safety (injury, fire…)
- Ensure Operation of Protective Devices
- Noise Control (esp. at high frequency)

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



- 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 A)
  - » Low R: (10A < I_f < 1000A)
- 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 Δ
  - » Overvoltages < 1.73 * V_{ln} 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