40 OHM GROUND FAULT RESISTANCE – STILL APPLICABLE?

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130K member customers
1,000 square miles territory
44 substations (48 transformers)
12.5 kV - 9,121 miles of line
92% residential by customer
System peak demand 550 MW
Wholesale Power Supplier – Great River Energy

Owned by the members we serve.
OUTLINE

- Definition – ground fault resistance
- Basis for research
- History of ground fault resistance value
- Practices among utilities
- Recent testing and publications
- Conclusion
GROUND FAULT RESISTANCE

Resistance through return path between faulted conductor and transformer source

A

B

C

N
Assume:
15 MVA transformer with $Z = 5.75\%$
Line impedance $Z_L = 1.4 + j1.7\ \Omega$
1 mile 4/0 ACSR
3 miles 1/0 ACSR

Bolted Fault: $0\ \Omega\quad 3470\ \text{amps}$
Fault impedance: $40\ \Omega\quad 173\ \text{amps}$
2011 – 2015 Project –
- Replaced KS line fuse with T fuses
- Audit system: fix & optimize coordination

On going challenge:
- Protecting for “minimum fault”
- “Standard” has been 40 ohms
- If we could squeeze in one more layer of fuse sizes...

Question: do we **have** to use 40? How about 30??
Limited to 40 amp fuse

140 Gnd Trip
400 Phase Trip

164 min fault
DISTRIBUTION – LOOPED TAP

Load
25 amps

Load
25 amps
Question:
Is the “40 ohm rule” still applicable?

Goal:
• Investigate opportunity to apply lower value to improve sectionalizing coordination

Considerations:
• Continue conformance with industry practices
• Safety is not compromised

https://www.youtube.com/watch?v=WdekH0UnWXk
GROUND FAULT IMPEDANCE HISTORY

- Study and engineering report – Edison Electric Institute (EEI) & Bell Telephone in 1937
- Ground fault impedance testing with staged faults – measured impedance in range of 5 to 20 ohms
- Some utility companies adopted 20 ohms as standard – one adopted 40 ohms

REA published Bulletin 61-2 in 1953; recommended:
- 40 ohms for substation transformers 5000 kVA and less
- 30 ohms of OH lines & 10-20 ohms for UG lines for transformers > 5000 kVA

Many coops adopted 40 ohms as standard

- OH line 30-40 ohms >5000 kVA transformer, 40 ohms 5000 kVA and less
- UG line 10-20 ohms
- “40 ohm rule” was intended to be guild line, not cast-in-stone rule

CRN Study 1997 – Ground Fault Impedance Values for System Protection

- Same conclusions as RUS bulletin (did not conduct actual testing)
- CRN & other documents state “other values and methods may be applied” - up to the Coop’s engineer
RECENT TESTING...

• IEEE and ABB research
  – testing by dropping energize line on various surfaces
• High impedance faults $R >> 40$ ohms
  – cannot be detected by traditional means
E. Surface Current Levels

Current Level in Amperes

Figure 3. High impedance fault current levels

# Fault Current Amps Based on Resistance

<table>
<thead>
<tr>
<th>Surface</th>
<th>Current (Amps) from Figure 3</th>
<th>Corresponding impedance (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry asphalt, concrete or dry sand</td>
<td>&lt; 5</td>
<td>&gt; 1400</td>
</tr>
<tr>
<td>Wet sand</td>
<td>&lt; 20</td>
<td>&gt; 360</td>
</tr>
<tr>
<td>Dry sod</td>
<td>20</td>
<td>360</td>
</tr>
<tr>
<td>Wet sod</td>
<td>40</td>
<td>180</td>
</tr>
<tr>
<td>Dry grass</td>
<td>25</td>
<td>288</td>
</tr>
<tr>
<td>Wet grass</td>
<td>45</td>
<td>160</td>
</tr>
<tr>
<td>Reinforced concrete</td>
<td>70</td>
<td>103</td>
</tr>
</tbody>
</table>
VALUES / METHODS USED ACROSS UTILITIES

- 40 ohms (across any coops, based on REA / RUS Bulletins)
- Calculate fault current using multiplier of load current
- Apply percentage of bolted fault current
- No fault impedance (assume bolted fault)
Began recording fault current values in 2011
Findings from fallen lines:

- Higher fault current values ("low" impedance) \(< 30 \text{ ohms}\)
- Lower fault current values ("high" impedance) \(> 40 \text{ ohms}\)
CONCLUSIONS

- Z fault values are generally NOT in the 30 to 40 ohm range
  - based on testing by others and internal measurements

- “Ground Fault Impedance is a design number for purpose of modeling and protection/coordination design”
  - not intended to represent actual impedances and current values

Changing from 40 to 30 ohms:

✓ enables better sectionalizing > enhanced reliability
✓ will not measurably compromise public safety
✓ Still complies with acceptable industry practices
TEAM

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Questions