Lessons Learned From Generator Destructive Testing

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Overview

• History and introduction to Little Falls
• Generator winding layout and fault survey
• Test setup and fault switch requirements
• Test results
• Conclusion
Little Falls Generation Station

Construction of Little Falls Generation Station (Feb. 17, 1910)
Turbine Housing Transported by Horse-Drawn Sled (Jan. 18, 1910)

Francis Turbine Delivered by Tractor (April 28, 1910)
Turbine Hall Under Construction (1910)

Little Falls Turbine and Generator Hall
**Little Falls Generation System**

![Diagram of Little Falls Generation System]

**Planning Process**

**Joint Meetings**
- Iterative/collaborative
- Stakeholders from within Avista: technicians, electricians, and engineers

**Test Plan**
- Detailed test setup
- Drawing markups
- Procedure for placing each fault with diagrams of windings
- Focus on safety
Generator Winding Layout

Access Point for Creating Faults

- $F_2 = 1T$
- $F_7 = 6T$
- $F_1$
- $F_9 = 2T$
- $F_{10} = 3T$
- NGR
- NGT
- A-Phase
- B-Phase
- C-Phase
- F_0
Branch CT Location 3

Test Setup
Data Acquisition for the Test

Fault Switch Rating

Double Phase-to-Ground Fault

\[
I_{FLT} = 3 \cdot \frac{V_1}{X_d^v + \frac{X_d^v + X_q^v}{2} + Z_0} \quad (Z_0 = 0.05 \, \text{pu})
\]

\[
= 8.11 \, \text{pu}
\]

\[
I_{FLT\_MAX\_SYM} = 10.41 \, kA \quad (1 \, \text{pu} = 1.284 \, kA)
\]

\[
I_{FLT\_MAX\_ASYM} = 18.3 \, kA
\]
The Fault Circuit

Test Results
What is the effect of a shorted rotor pole?

Effect of a Shorted Rotor Pole
One Out of 48 Poles Is Shorted

Split Phase Currents for Rotor Interturn Faults
Rotor Turn Faults Can Be Seen in the Stator Zero-Sequence Voltage

Stator Turn-to-Turn Faults
Branch Currents for a Turn-to-Turn Fault (Split Phase Currents)

Effect of a Stator Turn-to-Turn Fault on the Field Current
Estimated Circulating Current Calculations

\[ I_{CIRC} = \frac{k \cdot V_N}{X_{L'} N_{Branch} - 1} + X_{L'} (1 - k) \]

\[ k = \frac{N_{Coils\_shorted}}{N_{Coils}} \]

Phase-to-Phase Fault Test

<table>
<thead>
<tr>
<th>Terminal Voltages (V)</th>
<th>Neutral Side Currents (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAB</td>
<td>IA-1, IA-2, IA-3</td>
</tr>
<tr>
<td>VBC</td>
<td></td>
</tr>
<tr>
<td>VCA</td>
<td></td>
</tr>
</tbody>
</table>

Field Current (A)

Time (s)

Current (A)
Terminal Voltage

$V_{AB}$
$V_A$
$V_{B_C}$
$V_C$
$V_{CA}$
$V_B$
$N$

Insert Phase - to - Phase fault Video Here
Interbranch Fault or Double-Point Grounding on Same Winding

Terminal Voltages and Currents and Field Current
Voltages and Currents for Double-Point Ground Fault

Voltage Mag. \( V_N \) (pu) vs Time (s)

Current Mag. (pu) vs Time (s)

1st SLG 2nd SLG ???
Insert Double Phase-to-Ground fault video Here

Damaged Windings and the Branch CT
Connection of Fault Switch to Fault Point

Fault Points
Conclusion

• Using the generator winding configuration, we determined which faults are most likely to occur (fault survey)
• Obtained very rare high-resolution stator and rotor voltage and current recordings of generator faults
• Staged fault testing helps engineers:
  ▪ Improve generator protection functions
  ▪ Validate generator simulation models

Conclusion

• Detailed planning is required to select correct fault switch and to reduce testing errors
• Future scope is to validate some of the new protection functions and simulation models

This experience was an absolute “blast”!
How Many Folks Does It Take to “Destroy” a Generator?

Questions?