Accelerated Weathering of Overhead Loadbreak Switch Interrupters NEETRAC

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High Voltage Switch Subcommittee
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Introduction

• NEETRAC completed a scoping study to identify field problems with distribution loadbreak switch interrupters in 2005.
• Utilities reported problems with “stuck” interrupters or failures when opening.
• 17 loadbreak interrupters were removed from field service and returned to NEETRAC for evaluation.
• Many of the problems with these units appeared to be caused by UV deterioration and corrosion.
Field Evaluation

Returned from Field Service: Alabama Power Company
Field Evaluation

Returned from Field Service: Alabama Power Company

- Tracking Down Exterior Surface of Barrel
- Plastic Housing for Spring Broken Off
- Fiberglass Operating Rod
- Discoloration on Surface of Fiberglass Tube
- Vent Port at Upper End of Fiberglass Tube
- Nylon or Polyethylene Plug Serves as Guide Bushing for Bronze Push Rod
Field Evaluation

Returned from Field Service: Dominion
Accelerated Weathering of OH Loadbreak Interrupters

• Based upon a review of the units returned from the field, a project was initiated to investigate the affects of both UV deterioration and corrosion on new interrupters.

• Six different loadbreak interrupters from five manufacturers were exposed to both UV / condensation and salt-fog accelerated weathering at NEETRAC.

• Benchmark tests were performed during the aging process to measure dc contact resistance and mechanical force required for operation.
Accelerated Weathering of OH Loadbreak Interrupters

• Both new and aged interrupters were then subjected to the full load current interruption tests according to Section 9.1 of IEEE C37.34 at a high power laboratory.

• Failures from the full load current interruption tests were examined to assess the impact of the weathering on performance.
Samples Tested

S&C Electric Company
Omni-Rupter
17 kV, 900 A
147442R1-Z3-S115

S&C Electric Company
Alduti-Rupter
17 kV, 600 A
137512R7-S102
Samples Tested

Bridges
Vector
25 kV, 900A
PN963XF-41AS

A. B. Chance
Automation Ready
29 kV, 900 A
AR114MSLP
Samples Tested

Cooper Power Systems
M-Force
25.8 kV, 900 A
M2A41SC3AT

Inertia
25 kV, 600 A
TRS26STSHX1125
UV / Condensation Aging

UV / condensation aging according to ASTM D4329-05 and ASTM G154-06 using UVA-340 lamps.
UV / Condensation Aging

- 2,000 hours total aging was required to produce results similar to those observed on field aged units (includes UV & condensation periods).
- The following aging cycle was used:
  - 8 hours of UV at 60 ± 3 °C
  - 0.25 h water spray (no light), temperature not controlled
  - 3.75 h condensation at 50 ± 3 °C
- Rotation of samples approximately every 333 hours, horizontally across the rack.
- Distilled water was used for the chamber.
Salt-fog Aging

• Performed on one sample of each design after 2,000 hours of UV / condensation aging.
• 1,000 hour salt-fog aging test according to ASTM B117-07.
• A continuous fog of 5% salt solution was used.
Benchmark Tests

- dc contact resistance (closed position)
- Mechanical performance – torque, force, etc. (both opening and closing)
- Performed on the samples four times:
  - new
  - after 1,000 hours of UV aging
  - after 2,000 hours of UV aging
  - after 1,000 hours of salt-fog aging
- Sample designations:
  - UV is UV / Condensation aging only
  - UVS is UV / Condensation and Salt-fog aging
## Benchmark Test Results

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>dc Contact Resistance in Ohms</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Post 1,000 hr UV Aging</td>
</tr>
<tr>
<td>A-UV-5</td>
<td>0.085</td>
<td>0.158</td>
</tr>
<tr>
<td>A-UVS-6</td>
<td>0.067</td>
<td>0.339</td>
</tr>
<tr>
<td>D-UV-4</td>
<td>0.003</td>
<td>0.006</td>
</tr>
<tr>
<td>D-UV-5</td>
<td>0.009</td>
<td>0.007</td>
</tr>
<tr>
<td>D-UVS-6</td>
<td>0.004</td>
<td>0.014</td>
</tr>
<tr>
<td>E-UV-4</td>
<td>0.297</td>
<td>0.379</td>
</tr>
<tr>
<td>E-UVS-5</td>
<td>0.485</td>
<td>0.230</td>
</tr>
<tr>
<td>E-UV-6</td>
<td>0.176</td>
<td>0.286</td>
</tr>
<tr>
<td>F-UV-4</td>
<td>0.006</td>
<td>0.034</td>
</tr>
<tr>
<td>F-UVS-5</td>
<td>0.063</td>
<td>0.015</td>
</tr>
<tr>
<td>F-UV-6</td>
<td>0.004</td>
<td>0.028</td>
</tr>
<tr>
<td>G-UV-4</td>
<td>0.007</td>
<td>0.018</td>
</tr>
<tr>
<td>G-UVS-5</td>
<td>0.009</td>
<td>0.020</td>
</tr>
<tr>
<td>G-UV-6</td>
<td>0.006</td>
<td>0.007</td>
</tr>
<tr>
<td>H-UV-4</td>
<td>0.054</td>
<td>0.081</td>
</tr>
<tr>
<td>H-UVS-5</td>
<td>0.068</td>
<td>0.019</td>
</tr>
<tr>
<td>H-UV-6</td>
<td>0.039</td>
<td>0.031</td>
</tr>
</tbody>
</table>
### Benchmark Test Results

**Sample D-UVS-6 had to be lubricated with rust buster and forced open in order to record the post salt-fog aging measurements.**

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Initial Open to Closed Contacts</th>
<th>Initial Closed to Open Contacts</th>
<th>Post 1,000 hr UV Aging Open to Closed Contacts</th>
<th>Post 1,000 hr UV Aging Closed to Open Contacts</th>
<th>Post 2,000 hr UV Aging Open to Closed Contacts</th>
<th>Post 2,000 hr UV Aging Closed to Open Contacts</th>
<th>Post 1,000 hr Salt-Fog Aging Open to Closed Contacts</th>
<th>Post 1,000 hr Salt-Fog Aging Closed to Open Contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-UV-4</td>
<td>9.8</td>
<td>8.2</td>
<td>10.0</td>
<td>9.8</td>
<td>11.0</td>
<td>10.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-UV-5</td>
<td>11.4</td>
<td>9.9</td>
<td>12.4</td>
<td>10.2</td>
<td>10.5</td>
<td>10.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-UVS-6</td>
<td>9.6</td>
<td>8.8</td>
<td>9.8</td>
<td>10.8</td>
<td>10.0</td>
<td>10.3</td>
<td>13.9</td>
<td>9.9</td>
</tr>
<tr>
<td>D-UV-4</td>
<td>25.0</td>
<td>18.0</td>
<td>22.9</td>
<td>21.0</td>
<td>20.7</td>
<td>19.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-UV-5</td>
<td>23.7</td>
<td>20.0</td>
<td>23.0</td>
<td>19.0</td>
<td>21.9</td>
<td>21.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-UVS-6</td>
<td>23.0</td>
<td>21.0</td>
<td>19.9</td>
<td>22.2</td>
<td>20.1</td>
<td>19.4</td>
<td>24+</td>
<td>26+</td>
</tr>
<tr>
<td>E-UV-4</td>
<td>0.6</td>
<td>7.8</td>
<td>0.6</td>
<td>8.1</td>
<td>0.4</td>
<td>7.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-UVS-5</td>
<td>0.9</td>
<td>7.6</td>
<td>0.4</td>
<td>7.5</td>
<td>0.9</td>
<td>7.9</td>
<td>2.0</td>
<td>8.2</td>
</tr>
<tr>
<td>E-UV-6</td>
<td>0.9</td>
<td>8.4</td>
<td>0.6</td>
<td>8.2</td>
<td>1.0</td>
<td>7.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Benchmark Test Results

### Force Measurements in lbs

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Initial</th>
<th>Post 1,000 hr UV Aging</th>
<th>Post 2,000 hr UV Aging</th>
<th>Post 1,000 hr Salt-Fog Aging</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open to Closed Contacts</td>
<td>Closed to Open Contacts</td>
<td>Open to Closed Contacts</td>
<td>Closed to Open Contacts</td>
</tr>
<tr>
<td>F-UV-4</td>
<td>13.9</td>
<td>9.8</td>
<td>14.5</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-UVS-5</td>
<td>15.0</td>
<td>9.8</td>
<td>16.0</td>
<td>10.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-UV-6</td>
<td>15.3</td>
<td>9.8</td>
<td>18.7</td>
<td>10.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-UV-4</td>
<td>0.3</td>
<td>12.9</td>
<td>0.8</td>
<td>13.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-UVS-5</td>
<td>0.4</td>
<td>12.0</td>
<td>0.9</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-UV-6</td>
<td>0.4</td>
<td>11.9</td>
<td>0.5</td>
<td>11.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-UV-4</td>
<td>3.8</td>
<td>15.0</td>
<td>0.9</td>
<td>15.0</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-UVS-5</td>
<td>5.7</td>
<td>17.0</td>
<td>0.9</td>
<td>15.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-UV-6</td>
<td>2.7</td>
<td>19.0</td>
<td>1.2</td>
<td>16.1</td>
</tr>
</tbody>
</table>

**Note:** The table above shows the initial force measurements and the force measurements after various aging processes. The processes include UV Aging at 1,000 hours and 2,000 hours, and Salt-Fog Aging at 1,000 hours.
Load Current Interruption Tests

- Performed at Powertech Labs – October 2007
- IEEE Std 1247™ 2005, Clause 8.3.2.1, Load-switching tests
Load Current Interruption Tests

Test plan for each manufacturer’s switch:

1. Perform 10 load break switching operations at 100% load with new (un-aged) interrupters (as required by IEEE Std 1247™). A five minute “cool down” period was provided between each switching operation.

2. If the unit passed IEEE Std 1247™ requirements, replace interrupters with new (un-aged) interrupters and perform three additional load break switching operations under wet conditions. Prior to each operation, each interrupter was thoroughly wetted with water using a spray bottle with $100 \pm 15 \, \Omega \cdot \text{m}$ water. A five minute “cool down” period was provided between each switching operation.
Load Current Interruption Tests

3. Replace interrupters with the **aged units** (two UV aged only and one UV + salt-fog). During setup / calibration, locate the pole that opens first and install the UV + salt-fog interrupter at that location. Perform **10 load break switching operations** at 100% load. If an interrupter fails, substitute a new interrupter to try to complete the series to gain as much data as possible from the tests. A five minute “cool down” period was provided between each switching operation.

4. If the unit passed the requirements in (3), perform **three additional load break switching operations** under **wet conditions**. Prior to each operation, each interrupter was thoroughly wetted. A five minute “cool down” period was provided between each switching operation.
## Load Current Interruption Test Results

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Number of Successful Interruptions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New (10)</td>
</tr>
<tr>
<td>D</td>
<td>7 *1</td>
</tr>
<tr>
<td>F</td>
<td>8</td>
</tr>
<tr>
<td>E</td>
<td>10</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>H</td>
<td>10</td>
</tr>
<tr>
<td>G</td>
<td>4</td>
</tr>
</tbody>
</table>

Notes:

*1 – Switch was removed from field service. Interrupters were not new.

*2 – New and aged interrupters’ mounting brackets were different. Aged units could not be tested.

*3 – Only the aged F-UV-6 interrupter completed the three wet tests.

*4 – Interrupters pickup hooks were not replaced after the tests on new interrupters. These worn hooks may have contributed to the failure of the aged interrupters.

*5 – Wet tests were performed on the original new interrupters (13 total operations on same units).

*6 – Wet tests were not performed on the aged interrupters due to previous failures.
Benchmark Test Observations

• dc contact resistance measurements did indicate problems with samples D-UVS-6, G-UVS-5, and H-UVS-5 after the salt-fog aging.
• Force measurements also indicated problems with D-UVS-6 after the salt-fog aging.
Interruption Test Observations

• Wet tests did not affect results of the load current interruption tests.

• Three of the interrupters were **definitely affected** by the accelerated weathering tests.
  – D-UVS-6 seized up due to corrosion.
  – F-UV-4 and F-UVS-5 failed after only three successful interruptions.
  – H-UVS-5 experienced corrosion of a riveted connection that vaporized during testing, but none-the-less passed as the connection arced over.
Interruption Test Observations

• Two of the interrupters *may have been affected* by the accelerated weathering tests.
  – Manufacturer E interrupter tests terminated early due to pickup clip failure.
  – Manufacturer G failed interruption tests (new units also failed).
• One interrupter was *definitely not affected* by the accelerated weathering tests.
  – Manufacturer A interrupter passed all of the tests.
Recommendations for IEEE C37.34

- Add requirements for accelerated UV / Condensation aging prior to interrupting tests in Section 9 for usual service conditions.
- Add requirements for accelerated UV / Condensation aging and salt-fog aging prior to interrupting tests in Section 9 for unusual service conditions involving contaminated environments.
Contact Info

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