Time-Effective Rapid Test Procedures for Pollution Testing of Different Types of Insulators

IGOR GUTMAN
“Time-Effective Rapid Test Procedures for Pollution Testing of Different Types of Insulators”

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Introduction-1: what is in IEC 60815?

Pollution performance
Introduction-2: what is in IEC 60507/61245?

• Solid layer test method
• Salt fog test method
  • Determination of maximum withstand voltage at given pollution level. This method cannot provide data to evaluate the actual flashover voltage or the margin between the withstand test and 50% flashover voltage. Not practically applicable, especially for statistical approach.
  • Determination of the 50% flashover voltage at a given degree of pollution. The applied voltage level in each test shall be varied according to the up-and-down method. Can provide data to evaluate the actual flashover voltage, but is quite time-consuming.
Example of up-and-down procedure

<table>
<thead>
<tr>
<th></th>
<th>FO</th>
<th>FO</th>
<th>FO</th>
<th>FO</th>
<th>FO</th>
<th>FO*</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td>FO</td>
<td>FO*</td>
<td>W*</td>
</tr>
</tbody>
</table>
Details on standard solid layer

1. Dipping in Slurry
   - Salt Water + Kaolin

2. Drying

3. Wetting (Steam Fog) and Voltage
   - 100 min.
Details on standard salt fog

- Atomized Salt Water
- Energized Test Object

3m 1 Hour Test Time 3m
History of solid layer based method (RFO)

- Proposed by Lambeth and Tourreil: 1970-1980ies
- U-curve of flashover voltages
- Repeatable
Other historical applications of RFO

<table>
<thead>
<tr>
<th>$H_{ins}$ [m]</th>
<th>$S^a/D^b$ [cm]</th>
<th>Test method</th>
<th>$\nu$dripping [\mu S/cm]</th>
<th>$U_{50%}$ [kV]</th>
<th>FO stress [kV/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2</td>
<td>17/28</td>
<td>IPS</td>
<td>169</td>
<td>419</td>
<td>130</td>
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<tr>
<td></td>
<td></td>
<td>Up-and-down</td>
<td>172</td>
<td>390</td>
<td>121</td>
</tr>
</tbody>
</table>

a. $S$ - spacing between the bells.
b. $D$ - diameter of the bell.
Comparison of $U_{\text{min}}$ and $U_{50\%}$

- **Russian paper from 1970ies**: “Specially performed tests revealed that the average flashover voltages obtained by standard (i.e. up-and-down) and “smooth ramping” methods were approximately the same.”
- Results of testing of 2500 insulators with natural pollution
History of salt fog based method (QF)

- The test procedure for the Quick Flashover Salt Fog test (later called QF) was developed in parallel with the RFO test (P.J. Lambeth, C. de Tourreil: “Electrical performance measurements of artificially and naturally aged polymeric insulators”).
- “The RFO technique correlated well with the other diagnostic methods used to monitor the state of the insulators during the salt fog and cement laboratory aging process: the QFO Salt Fog technique was not so satisfactory.”
- Later, this method was improved and at present it is considered as a possible technique as will be shown later.
RFO (STRI): artificial pollution, DC composites

<table>
<thead>
<tr>
<th>Years in service</th>
<th>Removed from</th>
<th>Increase in U_{50%} after 2 days of recovery, %</th>
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<tbody>
<tr>
<td>13</td>
<td>Skagerrak</td>
<td>9-23</td>
</tr>
<tr>
<td>17</td>
<td>Cabora Bassa</td>
<td>13</td>
</tr>
<tr>
<td>0</td>
<td>New [6]</td>
<td>8-22</td>
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![Graph showing time vs. test voltage](image1.png)
![Image of RFO component](image2.png)
RFO (Sediver): artificial pollution, AC glass
RFO (STRI-Sediver): artificial pollution, AC glass
RFO (STRI-ESKOM): artificial pollution, AC station insulators
RFO (RSE): artificial pollution, AC composites
RFO (STRI): artificial pollution, AC composites
RFO (STRI): natural pollution, AC ceramic
Rapid for distribution insulators: 1995/2015

<table>
<thead>
<tr>
<th>ω, μS</th>
<th>Test voltage U1, kV</th>
<th>No. of tests n1</th>
<th>No. of flashovers m1</th>
<th>Relative flashover frequency h1</th>
<th>U50%, kV</th>
<th>Voltage stress level e1</th>
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<tbody>
<tr>
<td>3</td>
<td>14.0</td>
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<td>54</td>
<td>0.6750</td>
<td>1.04</td>
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<tr>
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<td>29</td>
<td>0.3625</td>
<td>0.97</td>
<td>0.95</td>
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<td>12.0</td>
<td>160</td>
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<td>0.1063</td>
<td>0.89</td>
<td>0.84</td>
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<tr>
<td></td>
<td>11.0</td>
<td>1600</td>
<td>7</td>
<td>0.0044</td>
<td>0.62</td>
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<tr>
<td>10</td>
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<td>80</td>
<td>59</td>
<td>0.7375</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.0</td>
<td>160</td>
<td>42</td>
<td>0.2625</td>
<td>0.95</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.0</td>
<td>640</td>
<td>8</td>
<td>0.0125</td>
<td>0.84</td>
<td></td>
</tr>
</tbody>
</table>

Diagram:

- XXXX
- XXX
- OXXX
- O
- X=Flashover
- O=Withstand
- Test 1
- Test 2
- Test 3
- Test 4
QF (EGU, CESI): natural pollution, AC porcelain/composite
Final proposal for RFO (D1.44)

- AC and DC test voltage
- Test voltage to be first applied after 15 min. after start of wetting by standard fog according to IEC 60507
- The speed of voltage ramping about 6 kV/s
- Voltage step about 5% of flashover voltage
- Time duration at constant voltage level 5 min.
- Maximum total test duration 100 min.
- For simplification, the average between the lowest flashover level and the highest withstand level should be considered as $U_{\text{min}}$ in the RFO test
Final proposal for QF (D1.44)

- **Conditioning test:**
  - A conditioning period of 20 minutes is applied at the specified salinity level. The voltage at this stage is about 90% of the estimated flashover voltage.
  - After this conditioning period the test voltage is then raised in 5% increments, and kept for one minute at each level, until flashover. After flashover, the insulator is immediately re-energized at its initial voltage (90%) and the process is repeated until five flashovers are obtained. This part of the procedure finishes the conditioning of the insulator.

- **Main test:**
  - 90% of the average of the five flashover voltage values is applied to the insulator as a reference voltage.
  - The test voltage is then raised in steps of 2.5%…3.5% every five minutes until flashover.
  - The test is continued with 90% of the previous value of the flashover voltage until the required number of flashovers has been obtained. The relevant value of this test is characterized by the mean value of the flashover values after their level was stabilized.
Summary

- Optimal dimensioning of insulation requires preferable application of statistical approach according to IEC 60815-1, which in turn demands pollution flashover performance of insulators. The existing test methods are valid only for porcelain and glass insulators and are time consuming if using standard up-and-down procedure for voltage application. The general trend is thus to make the tests time- and cost-effective.

- The Rapid Flashover Method (RFO) based on solid layer proved its repeatability and partial reproducibility and was used with success for practical applications for AC and DC, for ceramic and composite insulators.

- The Quick Flashover Method (QF) based on salt fog was used with success for diagnostics of the flashover voltage of naturally polluted and aged porcelain and composite insulators.

- Both methods are under consideration of CIGRE working group D1.44 and the intention is to make a Round Robin test in different laboratories for further standardization.