Field and Laboratory Testing of Composite Insulators

_in order to obtain input for statistical dimensioning_

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Recently published documents

OUTDOOR INSULATION IN POLLUTED CONDITIONS: GUIDELINES FOR SELECTION AND DIMENSIONING
Part 1: General principles and the AC case

GUIDE FOR THE ESTABLISHMENT OF NATURALLY POLLUTED INSULATOR TESTING STATIONS
Dimensioning of insulation

- Principles of dimensioning
- Input 1: environment
- Input 2: flashover strength
- Outcome
- Verification and application

Optimized dimensioning of insulation

Overview: Pollution dimensioning

- Pollution Severity Estimation
- Pollution Flashover Strength Estimation
- Insulation design
- Verification

Required performance

- Pollution stress at site: probability density function \( f(\gamma) \)
- Probability for flashover at maximum operating voltage: cumulative distribution function \( P(\gamma) \)
- Multiplication of the \( f \) and \( P \) and the area under this curve defines the risk for flashover

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Optimized dimensioning of insulation

Pollution Severity estimation

- Maximum ESDD
- Distribution on insulator
- Number of “pollution events”
- Type of contaminants

Pollution Severity estimation

-Examples-

ESDD
Surface conductivity

DDDG

STRI
Input data from ESKOM: test stations

- Input 1: Statistical pollution data from test stations (ESDD, NSDD and DDDG)
- Input 2: Leakage current data converted in pollution performance curves (flashover voltage plotted against ESDD)

Input data from NamPower: test towers

- Input 1: Statistical pollution data from service measurements (DDDG)
- Input 2: Leakage current data converted in pollution performance curves (flashover voltage plotted against ESDD)
Dimensioning of insulation

- Principles of dimensioning
- Input 1: environment
- Input 2: flashover strength
- Outcome
- Verification and application

Optimized dimensioning of insulation

- Pollution Flashover Strength Estimation

- Dielectric strength of the insulators as function of pollution severity (U50 & Standard deviation)

Laboratory test results
Additional tests (if necessary)
Service/station experience
Conversion from lab to service
"Laboratory" Strength
Pollution Flashover Strength Estimation of line insulators (in service environment)
STRI Generic curves
CIGRE Curve
IEC creepage recommendation
Tests in the field

Pollution Flashover strength estimation
-Use of Available Field Experience-

<table>
<thead>
<tr>
<th>Code</th>
<th>Specific creepage distance, mm/V</th>
<th>Type</th>
<th>Material</th>
<th>Calculated flashovers for 1 minu- topar year</th>
<th>Number of flashovers at HPTS after 1 year</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>31</td>
<td>Long rod</td>
<td>SR</td>
<td>$10^9$</td>
<td>0</td>
</tr>
<tr>
<td>B-1</td>
<td>36</td>
<td>Long rod</td>
<td>SR</td>
<td>$10^9$</td>
<td>0</td>
</tr>
<tr>
<td>B-2</td>
<td>34</td>
<td>Long rod</td>
<td>SR</td>
<td>$10^9$</td>
<td>0</td>
</tr>
<tr>
<td>C-1</td>
<td>31</td>
<td>Long rod</td>
<td>SR</td>
<td>$10^9$</td>
<td>0</td>
</tr>
<tr>
<td>C-2</td>
<td>20</td>
<td>Long rod</td>
<td>SPM</td>
<td>$0.5$</td>
<td>0</td>
</tr>
<tr>
<td>D-1</td>
<td>36</td>
<td>Long rod</td>
<td>EPDM</td>
<td>$0.3$</td>
<td>0</td>
</tr>
<tr>
<td>D-2</td>
<td>35</td>
<td>Long rod</td>
<td>SPM</td>
<td>$9.1$</td>
<td>0</td>
</tr>
<tr>
<td>E-1</td>
<td>29</td>
<td>Long rod</td>
<td>Porce- lan</td>
<td>1.3</td>
<td>4</td>
</tr>
<tr>
<td>E-2</td>
<td>29</td>
<td>Long rod</td>
<td>PTFV</td>
<td>$10^9$</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>47</td>
<td>Capillan</td>
<td>Glass</td>
<td>$2.5$</td>
<td>4</td>
</tr>
</tbody>
</table>
Pollution Flashover Strength estimation
-Use of laboratory data-

1. Service adapted methods:
   • Solid Layer (Inland with NSDD)
   • Solid Layer for composite insulators
   • Solid Layer with recovery
   • Salt fog (Coastal, no NSDD)
   • Dry Salt Layer (Coastal, no NSDD)
   • Dust Cycle Method (Desert, Industrial with NSDD)

2. $U_{50\%}$ is preferable than withstand
3. Directly applicable for statistical dimensioning
Pollution Flashover Strength estimation
Laboratory method based on field experience-2

- Relatively high currents (sometimes hundreds of mA)

Pollution Flashover Strength estimation
Laboratory method based on field experience-3

- Hydrophobicity is reduced, but not to hydrophilic state
**Salt Fog test is not representative**

<table>
<thead>
<tr>
<th>Salinity (kg/m³)</th>
<th>Maximum current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>40</td>
</tr>
<tr>
<td>Test 2</td>
<td>40</td>
</tr>
<tr>
<td>Test 3</td>
<td>40</td>
</tr>
<tr>
<td>Test 4 a</td>
<td>40</td>
</tr>
<tr>
<td>Test 5</td>
<td>80</td>
</tr>
<tr>
<td>Test 6</td>
<td>80</td>
</tr>
<tr>
<td>Test 7</td>
<td>80</td>
</tr>
</tbody>
</table>

- This test was performed to obtain some additional information

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**Modified Solid Layer test**

- Glass or Porcelain
  - Washing + Drying
  - Application of pollution
  - Voltage testing

- Composite
  - Washing + Drying
  - Pre-conditioning
  - Application of pollution
  - Voltage testing

- Composite - recovery
  - Washing + Drying
  - Pre-conditioning
  - Application of pollution
  - Recovery
  - Voltage testing
Pollution Round Robin Test within CIGRE WG C4.03.03

1. STRI in Sweden: performed
2. ERSE SpA (former CESIRICERCA) in Italy
3. Chubu University in Japan
4. Tsinghua University in China
5. EGU in Czech Republic
6. Arizona State University in USA
7. SEVES (Sediver) in France
8. CEPRI in China
9. China Southern Grid in China
10. NGK in Japan
11. Manchester University in UK
12. CRIEPI in Japan
13. CEPEL in Brazil

Testing of insulators up to 800 kV DC or 1000 kV AC
Rapid Flashover tests

- With rapid flashover clean fog test, flashover voltage in obtained in 1 hour
- Test results ($U_{50\%}$ and $\sigma$) can be used for statistical dimensioning

Dimensioning of insulation

- Principles of dimensioning
- Input 1: environment
- Input 2: flashover strength
- Outcome
- Verification and application
Optimized dimensioning of insulation
Verification of design

Obtain preliminary optimal line design for different sections

Utilize:
• Collected data
• STRI Software

Based on:
• Required performance

Pollution Severity Estimation
Pollution Flashover Strength Estimation

Required performance

Verification

STRI Software
Based on Statistical Principles

Insulation design

Insulator Selection Tool (IST)
Benefits of IST program

• Guides and educates user in insulator selection process
• Can be used as marketing tool
• Provides detailed performance analysis
• Is expandable and can be customized
• Allows selection of most cost effective insulation solution
• Is an excellent tool for education
• Enables technical comparison of different line insulators based on availability requirements

Dimensioning of insulation

• Principles of dimensioning
• Input 1: environment
• Input 2: flashover strength
• Outcome
• Verification and application
Verification of IST results
Methods of statistical dimensioning of the outdoor insulation with respect to polluted conditions

Example 1: Scandinavian Fenno-Skan-2 project (500 kV DC)

- Detailed service and laboratory investigations
- Rather clean area
- High demand on MTBF: 20-40 years
- Specific creepage distance 27-29 mm/kV
Example 2-1: Refurbishment of Western Cape OHL (400 kV AC)

- Pollution event in the Western Cape during February 2006
- Service data
- High pollution severity
- Koeberg Insulator Pollution Test Station data
- Russian findings: relation between ESDD and surface conductivity

Example 2-2: Refurbishment of Western Cape OHL (400 kV AC)

<table>
<thead>
<tr>
<th>Type of Insulator</th>
<th>Specific Creepage Calculated by IST, mm/kV</th>
<th>Actual Specific Creepage, mm/kV</th>
<th>Performance during the Pollution Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porcelain Support</td>
<td>48</td>
<td>33</td>
<td>Flashed during pollution event</td>
</tr>
<tr>
<td>RTV-Coated Porcelain Support</td>
<td>25</td>
<td>27</td>
<td>No flashovers during pollution event</td>
</tr>
<tr>
<td>Glass Cap-and-Pin</td>
<td>40</td>
<td>16</td>
<td>Many flashovers during pollution event</td>
</tr>
<tr>
<td>Silicone Rubber Longrod</td>
<td>22</td>
<td>24</td>
<td>Withstood pollution event with discharge activity observed</td>
</tr>
</tbody>
</table>
IST and LPE: references

Dimensioning of composite insulators: recent references 2007-2010

12. I. Gutman, A. Denfalk: “Pollution tests for polymeric insulators made of hydrophobic transfer materials”, IEEE Transactions on Dielectrics and Electrical Insulation, Special Edition 2010 (accepted for the publication in March 2010)