Study Committee D1

Materials and Emerging Test Techniques

Paper D1-PS2-10828

TEST METHODS AND CRITERIA FOR VALIDATION OF FUNCTIONAL PROPERTIES OF COMPOSITE INSULATORS RELATED TO MATERIALS AND INTERFACES

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Background and goal

- Overhead line composite insulators are characterized by modern and approved technologies
- There is a lack of reliable service experience and proper documentation
- **Goal: Establish and verify appropriate test methods and criteria for validation of essential functional properties of composite insulators**

Analysis of service experience

- Collected experience 8.6 mln. (25% worldwide)
- Detailed data will be presented at INMR (Oct. 2022)

Application of Composite Insulators: Perceptions vs. Service Experience

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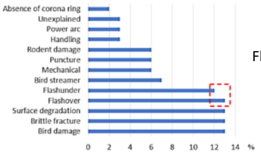
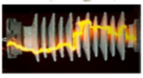
Dominant failure modes

- Flashunder due to poor adhesion core/housing accelerated by excessively high electric field
- Power companies often mix “flashunder” (interface core/housing) and “flashover” (along the housing)
- Ability to keep and recover hydrophobicity



Flashunder

Flashover

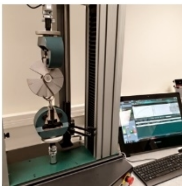


Test objects

- Thirty commercially available and purchased insulators from storage of utilities
- Seven manufacturers from Europe and Asia
- Years of manufacturing 2004-2020
- 72,5-420 kV; 100-500 kN
- HTV and LSR housings
- Standard and alternating profiles

Adhesion test method

- 100 h of water diffusion (I<0,1 mA) followed by pull-off test (>1.5 N/mm²)

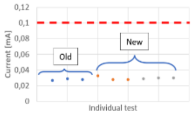


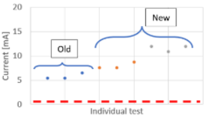
Adhesion test results

- Effectively demonstrates the difference in adhesion properties of commercial insulators
- High currents are confirmed by punctures
- The results are highly repeatable

Max current in water diffusion, mA	Average stress in pull-off test, N/mm²
Criterion: < 0,1 mA	Criterion: > 1,5 N/mm²
0,03	1,7
0,04	1,8
0,04	1,9
0,03	1,6
0,14	1,3
0,03	1,8
0,33[1]	1,8
3,8	0,5
0,25[1]	2,2
0,03	2,6
1,1	1,2
0,03	1,5
0,03	1,6
0,11[1]	1,0
0,2[1]	0,8
0,03	1,8
0,04	1,6
0,03	1,2
6,5	0,9
0,04	1,5
21,8	1,1
0,15	1,6
0,03	1,8

Note 1: remaining two measurements are within the criterion.





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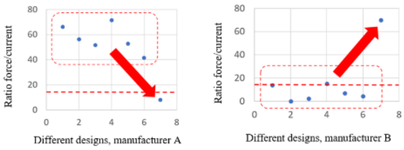
(continued)

Adhesion test results (cont.)

- Example of visualization creating two principally different clusters (insulators A and B)
- Dashed lines show the ratio 1,5/0,1=15



Water Drop Induced Corona (WDCI) test method

- Goal: Evaluates maximum axial electric field
- Test set-up and parameters as for RIV test, IEC 60437
- Difference is wetting of the bottom part by “IEC” water, 100 µS/cm
- Criterion: Visual observation of corona at maximum operating voltage

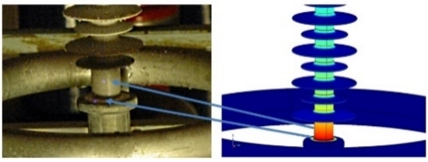
WDCI test results

- Results are compared with Comsol calculations using criterion 0,42 kV/mm (consensus in CIGRE/IEC)

Maximum average electric field stress calculated along 10 mm of the housing surface, kV/mm	Corona is seen in the WDIC test	
	From top	From bottom
0,46	Yes	Yes
0,39	Yes	Yes
0,34	No	No
0,44	Yes	Yes
0,34	No	No
0,24	No	No
0,25	No	No
0,24	No	No
0,32	No	No
0,34	No	No
0,26	No	No
0,41	No	No
0,33	No	No
0,29	No	No
0,33	No	No
0,44	Yes	Yes
0,40	No	No
0,27	No	No
0,28	No	No

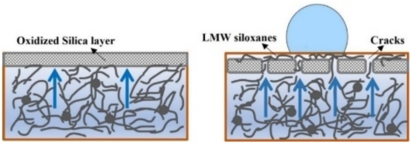
WDCI test results (cont.)

- Manufacturers are aware about the criterion 0,42 kV/mm, which reached consensus in CIGRE/IEC
- For calculated values above the criterion of 0,42 kV/mm (0,44-0,46 kV/mm), 100% of the electric field calculations were confirmed by the test (corona).
- For calculated values below 0,39 kV/mm (0,24-0,34 kV/mm), all thirteen electric field calculations were verified by the test (no corona), i.e., 100%.

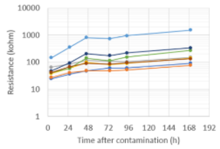


Dynamic hydrophobicity (recovery) test method

- Low Molecular Weight components penetrate pollution layer and encapsulate salts
- Electrical resistance of the pollution layer is gradually increased
- Top surface of pollution is not fully recovered yet



- Pre-conditioning by dry kaolin
- Application of SDD/NSDD 0,08/0,13 mg/cm^2
- Gentle wetting in humidification chamber
- Measurements of resistance over ca 160 hours
- Normalization R/R$_0$



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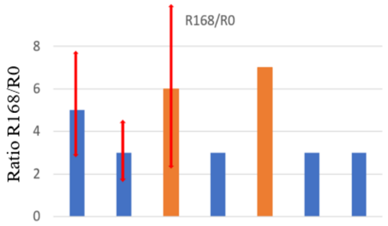
(continued)

Dynamic hydrophobicity (recovery) test results

- Results are completely agreed with “general insulator knowledge”
- HTV (blue) vs. LSR (orange) and HTV with different amount of filler (left bar)



Conclusions

- Adhesion test is representative and repeatable
- Water Drop Induced Corona test is fully supported by electric field calculations
- Dynamic hydrophobicity test reflects general insulator knowledge and can monitor dynamic hydrophobicity in service
- Tests are included in drafts of revised IEC Standards

Adhesion test in IEC (62217/61109)

11.6 Water diffusion tests on core with housing (E2)

Samples with rubber housing and one shed are cut perpendicular to the axis of the insulator with a diamond-coated circular saw blade under running cold water. It is recommended to use at least three samples with one shed per insulator, cut from the top, middle and bottom sections, see example in Figure 2. For relatively long insulators > 2 meters, the finally produced insulator lengths might be of higher interest to check the constancy of temperature required for vulcanization and bonding. The length of the test sample can vary from 25 mm to 35 mm, the diagnostic voltage will be adapted correspondingly.

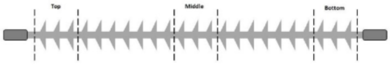


Figure 2 – Position of specimen generation

The test is to be done according to IEC 62217, clause 9.5.3

NOTE 1 Annex E describes additional mechanical methods applicable to verify the level of adhesion core/housing. *For sample tests pull-off test with manual cell or peel test are preferable.*

Electric field limits in IEC (61109)

To prevent the phenomenon of corona on string elements and water droplet corona, different thresholds were introduced:

1. electric field on the grading/corona ring and end fitting, proven by test and simulation [1, 2]; a criterion for maximum allowable field stresses is recommended with Emax < 18 kV/cm;

2. electric field along the housing surface, proven by test and simulation [1, 2]; a criterion for maximum allowable field stresses is recommended with Emax < 4.2 kV/cm averaged for 10 mm (surface coloured in green in Figure D.1);

3. electric field at the triple point at the sealing, see Figure D.1. If the sealant is exposed to the environment, an additional criterion for limitation of the electric field stress up to 3.5 kV/cm at the surface of the sealant (surface coloured in red in Figure D.1) is proposed.

The limitations are under consideration of CIGRE Working Group B2.57. The first limitation can be verified by a standard RIV test described in IEC 60437 [3] and IEC 61284 [4].

It should be mentioned that a test procedure to proof the water droplet behaviour was developed and widely tested. It is named Water Drop Induced Corona (WDIC) test [5, 6, 7, 8].

Dynamic hydrophobicity in CIGRE (TB 837)

Dynamic hydrophobicity applicable for after-service tests (future CSE paper from 10 power utilities)

Condition assessment of line composite insulators: after-service test programs and their practical application

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- By doing this test on the same batch of insulators each 5-10-20 years, it is possible to see the dynamics of the hydrophobicity, i.e., actual level of deterioration of this key property
- Utilities may exchange this standardized data for the same manufacturer