Study Committee B2

Overhead Lines

10669_2022

Application of Multi-stress Test Methods to evaluate Today`s Composite Insulator Reliability

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Motivation

- **Adhesion** on the interface between core and housing is a key property of a composite insulator:
  - Protects the core from moisture ingress and resulting leakage currents
  - Poor or missing adhesion has been found to be one of the major reasons for composite insulator failure
- **Nitric acid attack** was observed in service and some utilities adjusted their specification to request acid resistant silicone rubber housing:
  - Acid rain, industrial pollution or corona discharges can be sources of acids, aggregating on the surface of the insulators
  - Sulphuric (H2SO4) or nitric (HNO3) acid can attack silicone rubber housing and decrease its properties
  - The acids attack fillers (i.e. ATH):

$$2Al(OH)_3 + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 6H_2O$$
$$Al(OH)_3 + 3HNO_3 \longrightarrow Al(NO_3)_3 + 3H_2O$$

Investigations

- The aim of the investigations is to evaluate the adhesion quality of the test samples and compare new developed special water absorption test with adhesion evaluation according to IEC 62217
- Basic investigations on the influence of the acid attack on the resistance to tracking and erosion according to IEC 60587

Test Methods

- **Evaluation of adhesion:**
  - Test specimens: Insulators taken from service or produced specially for laboratory investigations
  - Pre-stressing by water immersion with thermal cycles (special water absorption test)
  - 30 min AC test with IR measurement of the shank temperature
- **Nitric acid attack:**
  - Test specimens: material samples for inclined plane test
  - Pre-stressing by immersion in nitric acid (pH = 1, 35°C) for different time intervals up to 2184 h
  - Additional pre-stressing by boiling in salt water according to IEC 62217

Conclusions of the Adhesion Evaluation

- High water ingress results in leakage currents along the interface, increasing shank temperature
- Special water absorption test using tap water was found to be more severe and detect improper adhesion compared to tests according to IEC 62217 by boiling in salt water
- Insulators with no adhesion can pass the IEC 62217 test if the sealing is applied appropriately
- Mechanical adhesion due to shrinkage and applied sealing can prevent moisture ingress in the interface during testing, but results in failures in service
- Insulators with LSR housing without adhesion can experience electrical failure during electrical testing after special water absorption test in contrast to tests according to IEC 62217
- Insulator samples taken from service with poor or no adhesion will fail the test according to IEC 62217 ($\Delta T >$ 20 K) and special water absorption test

Conclusions of the Influence of the Acid Attack

- Pre-stressing by acid attack:
  - Increases the area of the erosion (not limited to the vicinity of the lower electrode)
  - Increases the loss of mass, but only limited influence on the depth of erosion

Honeycomb pattern due to dissolution of the filler (ATH) from the rubber

- Additional pre-stressing by boiling:
  - Increases the area of bulk erosion up to the top electrode
  - Increases the depth of the bulk erosion
- Acid attack decreases the resistance to tracking and erosion and results in a different appearance of the erosion.
- Higher amount of filler (ATH) will have a positive contribution.

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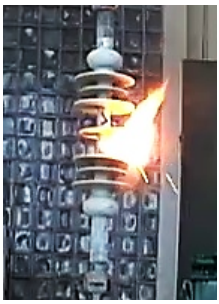
Tested Insulators

- Housing made of high temperature vulcanizing (HTV) and liquid silicone rubber (LSR)
- Variation of adhesion (no chemical adhesion, poor adhesion, adhesion by shrinkage)
- Sealing applied or not

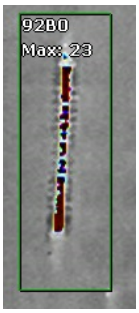
LSR with Poor Adhesion

Poor chemical adhesion, low mechanical adhesion
ΔT < 20 K, failure by puncture



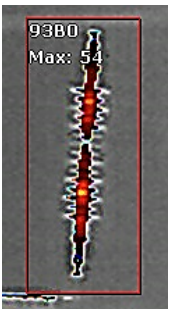
HTV without Adhesion and with Sealing

No chemical adhesion, high mechanical adhesion
No notable temperature increase, no failure. Sealing prevents moisture ingress and propagation along the interface.



HTV without Adhesion and no Sealing

No chemical adhesion, high mechanical adhesion
ΔT > 20 K. Failed testing according to IEC 62217.



Evaluation

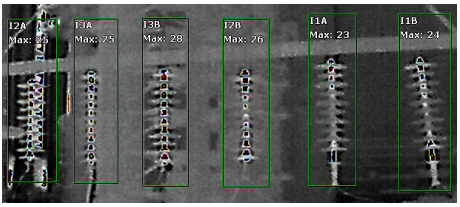
- Application of AC voltage for 30 min after defined number of cycles. No flashover / flashunder or puncture shall occur.
- Infra-Red (IR) temperature measurements during voltage test. The temperature rise shall not be higher than 20 K (IEC 62217 and IEEE C29.11).

Testing of Insulators Removed from Service

- Two 420 kV insulators with HTV housing
- One insulator with no adhesion
- Testing with boiling procedure according to IEC 62217 and special water absorption test

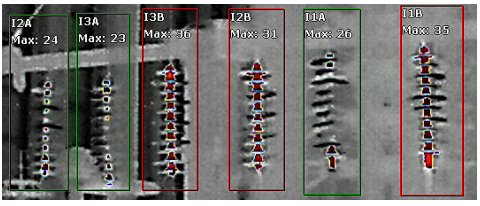
Testing According to IEC 62217

All samples pass 30 min AC withstand test



Testing with Special Water Absorption Test

Three samples prepared from one insulator fail 30 min AC withstand test



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Investigated Materials

Material	ATH [wt.-%]	ATH type
A	58	ATH 1, silane treatment A
B	52	ATH 1, silane treatment A
C	> 50	ATH 2, silane treatment B
D	54	ATH 3, silane treatment C
E	54	ATH 3, silane treatment D

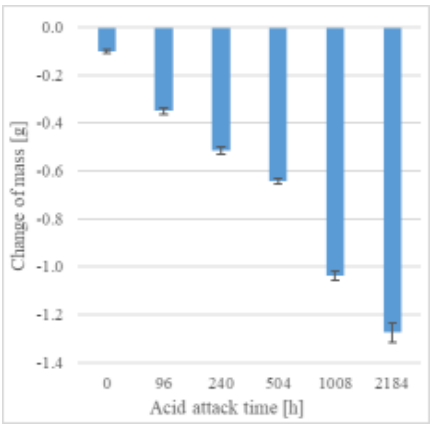
Test Procedure

- Acid attack intervals: 96, 240, 504, 1008, 2184 h
- Boiling intervals: 96, 168, 240 h
- Inclined plane test: 4.5 kV with 0.6 ml/min, 6 h

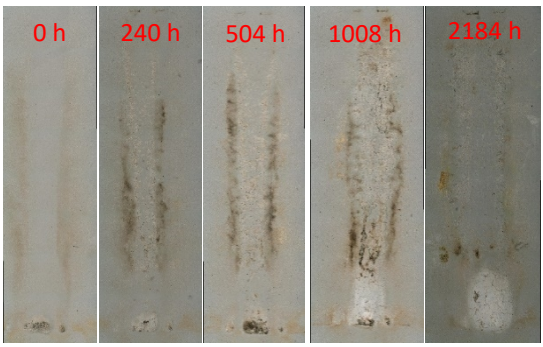
Evaluation

- Qualitative picture of the erosion
- Depth of erosion and change of mass

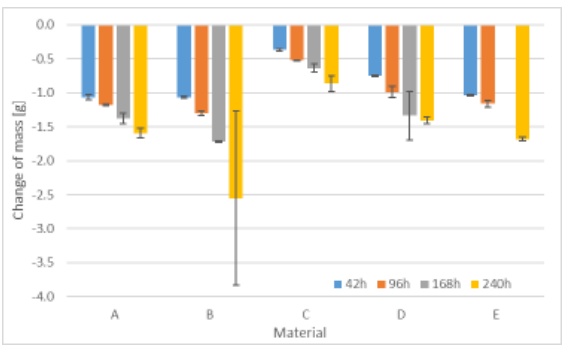
Change of Mass after Acid Attack



Honeycomb Erosion after Acid Attack



Change of Mass after Boiling for Different Materials



Increased Area of Erosion after Boiling