Optimisation of surface protection by super hydrophobic surfaces for medium sized distribution-transformers or inductive components in outdoor areas

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Introduction

Transformers are irreplaceable for the electric power supply
- the whole industry would stop! -

Transformers and other inductive components have to deal with the following problems:

REQUIREMENTS TO A TRANSFORMER

- sophisticated environment-friendly insulations
- low losses
- small dimensions
- outdoor area or rough industry
- high reliability
- low weight
- humidity and dirt
- resistances to environmental influences

Transformers have to deal with contemporary electrical and climatic stress!
The demand on higher and more sophisticated resistances grows steady!

It is of particular importance to reinforce the surface of materials to extend the lifetime of high voltage insulating systems!

This investigation deals with the ageing process of transformers and inductive components with modified insulating surfaces

Conventional protection

Transformers are used in outdoor areas and industrial environment.
A protection against environmental influences, like humidity and dirt is necessary:

So far housings with adequate IP protection classes are used. Higher IP classes require a proper sealing of the housing

Problem: The transformer needs a heat removal. This has to be done by the housing.

Potted or varnished inductive components without housing can be cooled easily by ventilation

It is easier to redeem needed air distances for high voltage transformers without housing. Furthermore there won't be any noise growth nor resonance vibrations (due to no housing walls).

How can the lifetime of inductive components be increased by an efficient dirt- or humidity protection without a housing?

Lotus Effect

„Lotus Effect" means a low wettability of a surface. Water rolls off as drops and takes along all dirt particles. A nanostructured surface like on the lotus leaf is the cause for this.

For some years there are already products on the market, which use the phenomenon of the „Lotus Effect":

- glass plate sealing
- lotus effect glasses
- burning-in coating for metals
- plasma polymer coatings
-bonding improvement of polyamide on copper

Unfortunately these products didn't prevail for the usage of electrical engineering yet.

- lack of persuasive tests in laboratories
-lack of persuasive field trials from practice
- suspense of a long-term performance

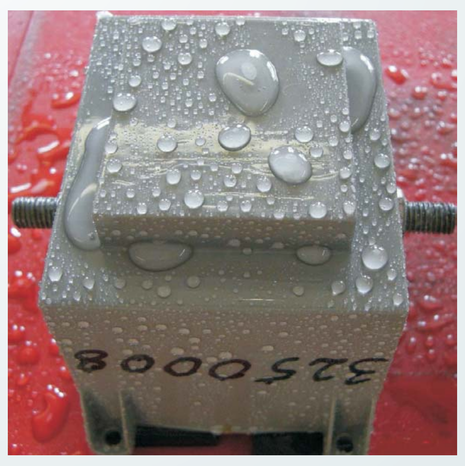
For epoxy cast resin systems the „Lotus Effect" could mean a distinct improvement of the hydrophobic characteristics.

Experiments

The „Lotus Effect" could be very useful especially in outdoor-, industrial- and automotive areas with very distinctive pollution layers.

A combination of ageing resistant insulation materials and a hydrophobic surface could contribute to an **improvement of the whole insulation system.**

The goal is to put dry transformers without housing in a high IP protection class.



Experiments

Each of the test items was examined **without** any manipulation beforehand to get comparable values.

Every test item was checked for:

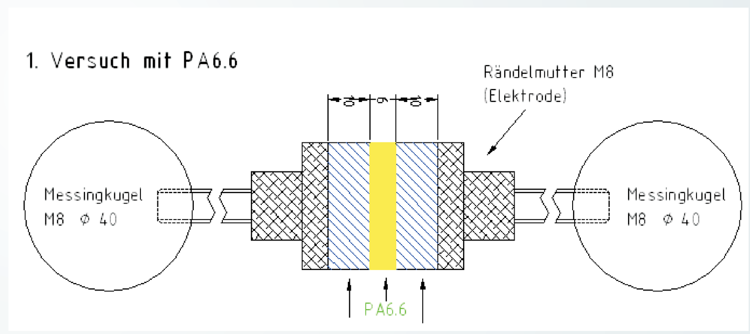
- leakage current
- partial discharge
- insulation resistance
- disruptive discharge between primary and secondary

To measure the deterioration of insulating materials, caused by infiltration of moisture, we built capacitors with electrodes.

The insulating material that is to be surveyed can be found between the electrodes.

Experiments

The first test type was a capacitor with knurled nuts as electrodes



problems: the knurled nuts are not adaptive as electrodes
➡ field cambers at the edges occur

executed tests: - partial discharge
- absorption of humidity
- no special coating

absorption of humidity test:
The test items were put into water for several hours. Afterwards they were dried at at 80°C and at 110°C.
Changes in weight before and after got compared.

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Wir formen den Strom und bringen Spannung

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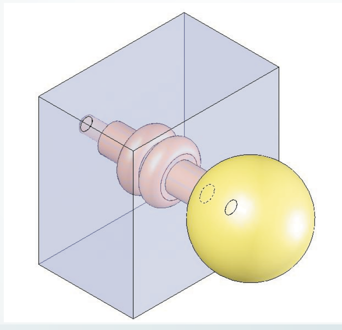
Experiments

The next test type was a capacitor with a Rogowski profile.
Rogowski profile means, the radius of the curve has to be larger than the distance of the electrodes.



problems: - homogeneous field requires very high voltages to receive measured values

executed tests:

before potting: - partial discharge
➡ flashover at 5 kV

after potting: - partial discharge
➡ still no partial discharge at 60 kV

Experiments

This time the test items used needlepoints as electrodes.

problems: - even these test items show discharges on the surface

executed tests:
- partial discharge after potting (ambient temperature)
- partial discharge after heating (110°C)
- partial discharge at chillness (0°C)
- partial discharge of items in transformer oil (dry and wet)
- partial discharge after 68h water accumulation
- leakage current up to 100 kV
- weight increase after 68h water accumulation
- extension of cast resin at 0°C, 20°C and 110°C

Experiments

Along with the tests about cast-resins, a test about hydrophobic coatings was done.

test item without coating

test item with coating

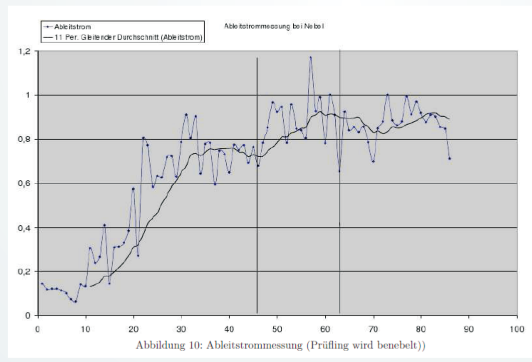
coating peels off

We did tests with two different coatings.
After coating, the test items were sprayed with a filled aerosol can to see how the hydrophobic surfaces react. Following this test, we did an absorption of humidity test and checked the difference in weight.

problems: - one coating peeled off the housing, the test items were very lubricious ➡ bad adhesion
- with the other coating, the test item absorbed the same amount of water as without coating

Experiments

To be able to do a proper characterisation of super hydrophobic surfaces, we need a more realistic test environment. To increase the ageing process, simultanous a chemical and electrical condition is needed (multi-stress-test).



constant bedewing is needed, while the test item has to deal with high voltages

➡ the latest upgrade for our tests was a mist chamber
With this chamber, we are now able to do further, more realistic tests about the behaviour of hydrophobic materials.

Results

TESTS WITH CAST-RESINS

-good hydrophobic characteristics

-mechanical and electrical qualities often didn't meet the high requirements

-tests about the simultaneous properties on different surfaces like iron, copper and polymeric surfaces are still missing

TESTS WITH HYDROPHOBIC SILICON COATINGS

- very good results regarding the hydrophobia

-bad results regarding the bonding of the coating to the component

- experiments with metallic surfaces still need to be done

- long-term stability wasn't tested either yet (bonding issues)

Outlook

Following our current series of tests, it is clear, that PU and PE cast-resins tend to have a decent adhesion without additional resources.
Furthermore some of the show good hydrophobic characteristics.

⬇

We came to think:
-to use a cast-resin, which makes an additonal coating unnecessary
- to use a cast-resin as a coating

Especially coatings, that didn't meet the mechanical and electrical requirements, but had decent hydrophobic characteristics will be tested as coatings.

Tests with super hyrophobic showed better results during multi-stress conditions than unprotected components:

- low leakage current
- low partial discharge
- reduced absorption of water

The long-term performance is still unknown and requires more tests though.

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