LONG TERM BEHAVIOUR OF OUTDOOR TERMINATIONS MADE OF SIR

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ABSTRACT

More and more cable accessories for medium voltage are made of SiR (Silicone rubber) and in special of LSR (liquid silicone rubber). The terminations show some great advantages - like wide range application, excellent ozone and UV-resistance and retention of hydrophobicity – compared to heat shrink terminations. Medium voltage terminations made of liquid silicone rubber with integrated refractive stress control element were tested in the outdoor test field at the University of Applied Science Zittau/Görlitz for 5,5 years. The terminations had a rated voltage of 12/20(24) kV. During the whole test a voltage of 18 kV was applied to the terminations and also the condition of the terminations was checked visually and flashover or breakdowns were recorded. After this long term test the overall condition of the terminations was checked and compared to the ratings given by new terminations to know if aging occurred during the tests.

These condition tests after 5,5 years consists of measurement of the contamination of the pollution layers, measurement of the hydrophobic class along the termination. Furthermore voltage test – AC-withstand voltage, lightning impulse tests and partial discharge test were made. After all these tests the terminations and the stress control element were dismantled and the edge of the outer semi conductive layer of the cable was visually checked if some electrical aging traces would have occurred during the tests.

From these results some recommendations for maintenance and design requirements for the creepage distance can be given.

INTRODUCTION

Since many years cable accessories are made of elastic materials mainly of silicone either liquid silicone rubber or high temperature vulcanizing silicone. The use of SiR has many advantages like wide range application, UV resistance - by the chemical formulation – and also tracking resistance [1, 2]. The retention of hydrophobicity and also the transfer of hydrophobicity through the pollution is also a known phenomenon [2, 3]. The behaviour of hybrid and silicone terminations under normal outdoor service conditions was investigated at HS Zittau/Görlitz from 1995…1999.

It was the goal of this investigation to carry out a long term test of outdoor terminations made of SiR under severe electrical conditions and to explore the behaviour of the terminations also under aged conditions.

TEST SETUP

The terminations of the type CAE-F 12/20(24) were mounted on both end of an 20 kV cable of the type NA2XS2Y 150RM/25 with a length of approximately 3 m in April 2004. **Fig. 1** shows the test setup after installation. Only 2 cables with 4 grey terminations were selected for this investigation. The other terminations were not used for this investigation.

Fig. 1: Installed test objects.

The terminations were mounted at the outdoor test field of the University of Applied Science Zittau/Görlitz. The climate during the tests was typical for Middle Europe with temperatures from -25°C…35°C consisting of dry and humid periods – e.g. fog, rain, snow and ice. The contamination range was from light to medium.

Fig. 2 shows a detailed view of the tested termination. The termination had a flashover distance of 335 mm and a creepage distance of 551 mm. This led to a specific creepage distance 23 mm/kV.

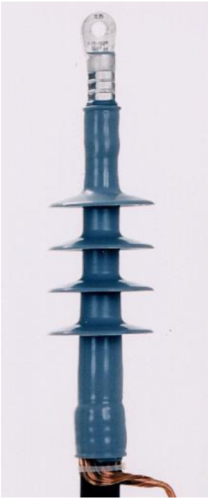

Fig. 2: Test object termination CAE-F 12/20(24)

The terminations were installed in April 2004. From this date until October 2009 – for a period of 5,5 years – a line to earth voltage of 18 kV_{eff} (1,5 times the phase to earth voltage under normal service condition) was applied continuously to the terminations. During this period the terminations were visually checked regularly and the voltage was continuously monitored if any irregularities occurred.
After this testing period two cables with the 4 test object were dismounted from the test stand and visual inspections and electric tests were done to characterize the remaining hydrophobic and dielectric properties of the terminations. The tests itself and the sequence of tests are shown in **Table 1**.

No.	Test performed	Test standard / test conditions
1	Visual check	-
2	Hydrophobicity	HC class acc. to IEC 62073 [4]
3	Leakage current	Done in clean fog conditions [5]
4	Partial discharges	Acc. to IEC 60270
5	AC withstand	54 kV_{eff} / 5 min acc. to EN 61442 [6]
6	BIL withstand	125 kVp / ± 10 times each acc. to EN 61442
7	Visual check	-

Table 1: Sequence of tests performed after the long term electric stress.

After all these tests the terminations were completely dismantled from the VPE-cable by cutting them off and a visual check of the interface SiR (termination) and VPE-cable (outer semi conductive layer and insulation layer) was made to see if partial discharges or degradation during the test period occurred.

TEST RESULTS

Results of the long term test

During the period of 5,5 years a phase to earth voltage of 18 kV_{eff} was continuously applied and neither a flashover nor a breakdown or even an over current tripping release occurred at all the tested terminations. The terminations withstood this stress without any problems.
In the following chapters the test results of the tests according to table 1 are described.

Visual check

Fig. 3 shows the surface of one termination representative for the test samples.

Fig. 3: detailed view of a termination after the long term electric stress.

Surface contaminations were visible but no damage on the silicone surface of the terminations could be noticed. There were neither creepage tracks nor erosion tracks on the surface of the termination visible.

Hydrophobicity

Fig. 4 shows a termination sprayed with water droplets to determine the hydrophobic class of the termination along the surface.

Fig. 4: Termination sprayed with water droplets.

The hydrophobicity was good to excellent across the whole surface of the terminations. The long term stability of the surface was proven and also the transfer of the hydrophobicity through the surface contamination was given during the whole test period of 5,5 years. The hydrophobic class was measured along the whole surface of the termination. **Fig. 5** shows the measuring points in detail.

Fig 5: Measuring points of the hydrophobic class spread along the surface of the termination.

The hydrophobic class in detail are shown in **table 2**.

Meas. point No.	CAE-F No. :	1	2	3	4
		HC-class			
1	Trunk	1	1	1	2
2	Shed upper side	1	1	1	1
3	Shed lower side	1	1	1	1
4	Trunk	1-2	2	2	2
5	Shed upper side	1	1	1	1
6	Shed lower side	1	1	1	1
7	Trunk	1-2	2	2	2-3
8	Shed upper side	1	1	1	1
9	Shed lower side	1	1	1	1
10	Trunk	1-2	3	2	3-4
11	Shed upper side	1	1	1	1
12	Shed lower side	1	1	1	1
13	Trunk	2	3-4	2	2-3

Table 2: detailed results hydrophobic class.

The hydrophobic class on the shed was from HC 1 to HC 2. Most of the parts of the trunk had also HC1 to HC 2 except a few portions showing HC 3-4.

Electrical tests

Leakage current measurement

This measurement was done under clean fog conditions. The conductivity of the fog was less than 10 µS/cm. The spray rate was 0,3…0,4 l/m³h. The leakage current was measured at test voltages from 14…36 kV with a voltage increase rate of 2 kV/10 min. During this test only a capacitive current was measured - comparably with the measurements of dry terminations. This also proves the hydrophobic conditions of the surface of the terminations.

Partial discharge measurement

This measurement was done acc. to IEC 60270. The voltage was raised to 27 kV kept constant for 60 s and than lowered to 24 kV. The measuring time was 5 min. **Table 3** shows the results of the PD measurement.

Test objects Type CAE-F 12/20 (24 kV)		Test voltage U_p	
		24 kV	27 kV
CAE-F Nr. 1	CAE-F Nr. 2	< 1 pC	< 1 pC
CAE-F Nr. 3	CAE-F Nr. 4	< 1 pC	< 1 pC

Table 3: PD measurement of the test objects.

The PD intensity was below 1 pC during the whole test.

Voltage withstand tests

The voltage withstand tests were performed in two parts; first an AC voltage withstand test with 54 kV/5 min and then a BIL voltage withstand test with 125 kV_p – 10 pulses each with positive and negative polarity were done. The results are shown in **table 4**.

Test objects Type CAE-F 12/20 (24 kV)		AC test	BIL test 1,2/50
		U_p = 54 kV / 5 min	$\hat{U}_p$ = 125 kV_P / 10 pulses (+/-) each
CAE-F No. 1	CAE-F No. 2	Passed	Passed
CAE-F No. 3	CAE-F No. 4	Passed	Passed

Table 4: results of the voltage withstand tests.

There was neither a flashover nor a disruptive discharge during the tests.

Visual Check

After all these tests the terminations were cut and dismantled from the cable. **Figs 6** and **7** show the overall view and a detailed view of the dismounted termination and the VPE cable resp.

Fig. 6: Overall view of the dismounted termination and the VPE cable.

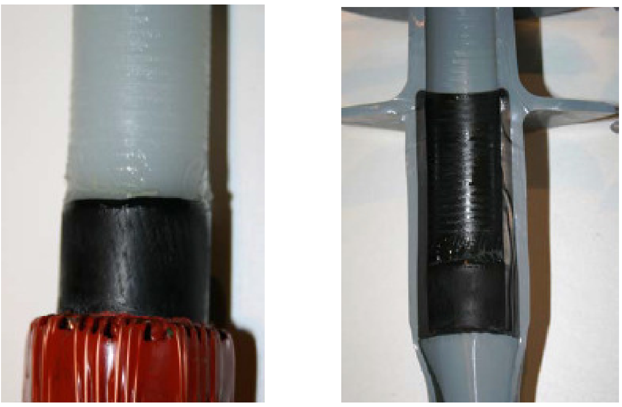

Fig. 7: Detailed view of the cable – outer semicon layer and VPE-insulation – and the corresponding part of the termination.

During this visual check no discharge traces could be found on the VPE cable and on the inner SiR-surface of the termination. The interface VPE-cable – SiR-termination was practically in new condition after all the conducted tests.

CONCLUSION

The terminations were tested during a period of 5,5 years at the outdoor test field of the University of Applied Science Zittau/Görlitz. The applied voltage was 18 kV (1,5 times the phase to earth voltage). During this time neither a flashover nor a breakdown occurred at all test objects. Also no over current tripping release happened.

During the visual check of the contaminated terminations after the test no surface damage could be found and also the hydrophobic class of the termination surface was in the range of HC 1 to HC 2 on most parts of the termination. Also nearly no leakage current beyond the capacitive current could be measured under clean fog conditions; this also proves the excellent hydrophobic surface conditions of the terminations. All the tested accessories withstood the required AC and BIL withstand voltages given in the relevant standard. Also no partial discharges could be measured at 2 times phase to earth voltage. After dismantling of the terminations and a visual check of the inner SiR – VPE interface no irregularities and inner partial discharge traces neither on the silicone stress element nor on the VPE could insulation layer of the cable be found.

These long term test shows that the hydrophobicity of SiR remain stable also during a period of more than 5 years and the electric properties of a termination with integrated refractive stress control element remain more or less unchanged compared to new ones. These results show that the long term behaviour of SiR terminations is excellent even when no maintenance or cleaning is done during the testing period. All this results were obtained during stress which was more severe than the normal electric service condition.

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