

Laboratory report

High Voltage Laboratory
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Impulse Voltage Tests at Insulated Down Conductors "HVI Standard" on 15 July 2010 and "HVI Light" on 20 July 2010

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1. Tasks – Objective of Tests

Objective of tests was to examine the creeping discharge resistance, the spark over resistance and the dielectric strength of the insulated down conductors "HVI Standard" and "HVI Light" (Part Nos. see annex 2).

In addition to former tests following items have been taken up into the test series and realized in extended test conditions.

Additional items and extended test conditions:

- The test specimen is carried in an earthed metal pipe over a length of 2 meters.
- The response time or time to crest T_C of the comparison arrangement (spark gap) has to be within a specified minimum time T_{Cmin} (here $T_C < T_{Cmin} = 2 \mu s$).

The first item ensures a sufficient test volume for proofing the dielectric strength of the insulating material and its quality.

The second item ensures an adequate minimum test voltage level for each spacing set at the comparison arrangement (spark gap).

The resulting voltage is testing the creeping discharge resistance as well as the spark over resistance of the insulated down conductors.

Creeping discharge resistance and spark over resistance had to be tested also at worse environmental conditions. For this purpose test series in dry and wet state were carried out. Two kinds of wet state series tests were carried out: Wetting with tap water and wetting with 5% NaCl solution.

A total of three (3) test loadings each at three (3) environmental conditions (dry, wet – tap water, wet – 5% NaCl solution) in three (3) test series, hence a total of 27 test loadings for each type of the insulated down conductors were required.

Additional requirements: Passing of three (3) load tests at equal environmental conditions of each specimen without failure. Three (3) different test specimen had to be used for each environmental condition. In order to limit the required total quantity of test specimen, multiple test series at the same specimen in compliance with the above conditional terms were allowed.

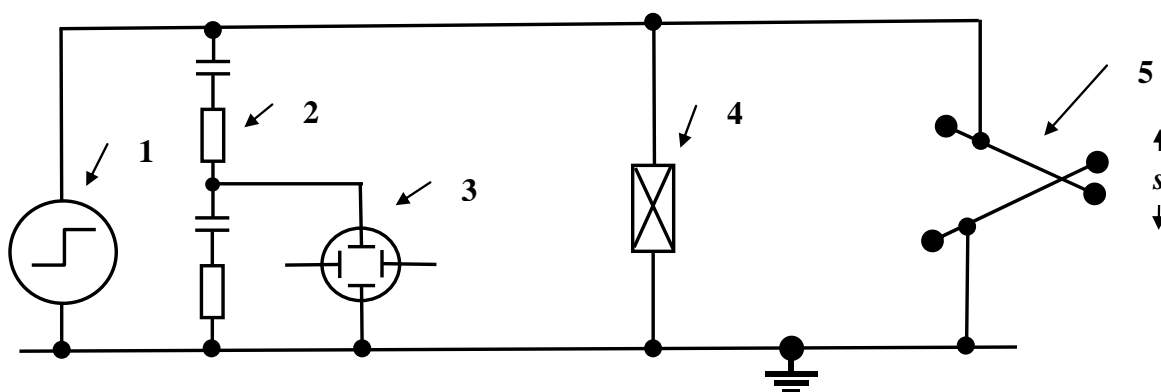
These determinations and the relatively wide scope of testing were provided for getting information about the constant manufacturing quality of the insulated down conductors.

2. Test Assembly

The test assembly comprises

- a 12-stage Marx generator with 1.2 MV total charging voltage and a related impulse voltage measurement system
- a test specimen (insulated down conductor) arranged as illustrated below and
- a comparison arrangement (spark gap) consisting of 2 crossed electrodes with adjustable clearance s .

Figure 1 shows a total view of the test assembly.



1. Impulse generator
2. Impulse voltage divider
3. Impulse measuring device
4. Test specimen
5. Comparison arrangement CA (spark gap)

Figure 1: Test assembly, total view

Figure 2 shows the arrangement of the specimen. An earthed clamp is fixed on both sides of the specimen in a distance of l_1 . This is the potential control area which will be tested for three (3) different environmental conditions (dry, wet – tap water, wet – 5% NaCl solution).

The middle section of the specimen is laid in an earthed metal pipe of length l_2 . On the left end 5a the specimen is connected with the impulse generator, on the right end 5b with the comparison arrangement (spark gap) terminal.

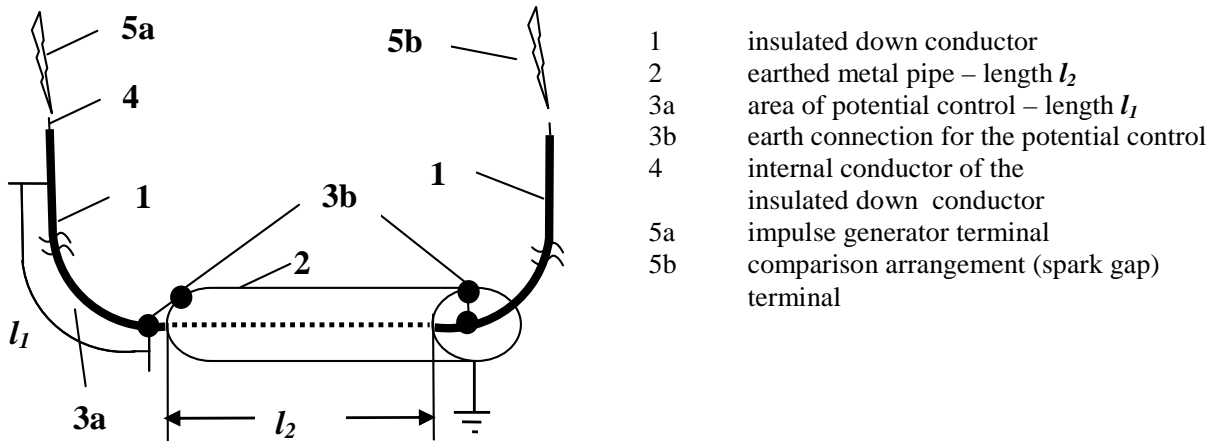


Figure 2: Test assembly, arrangement of the test specimen

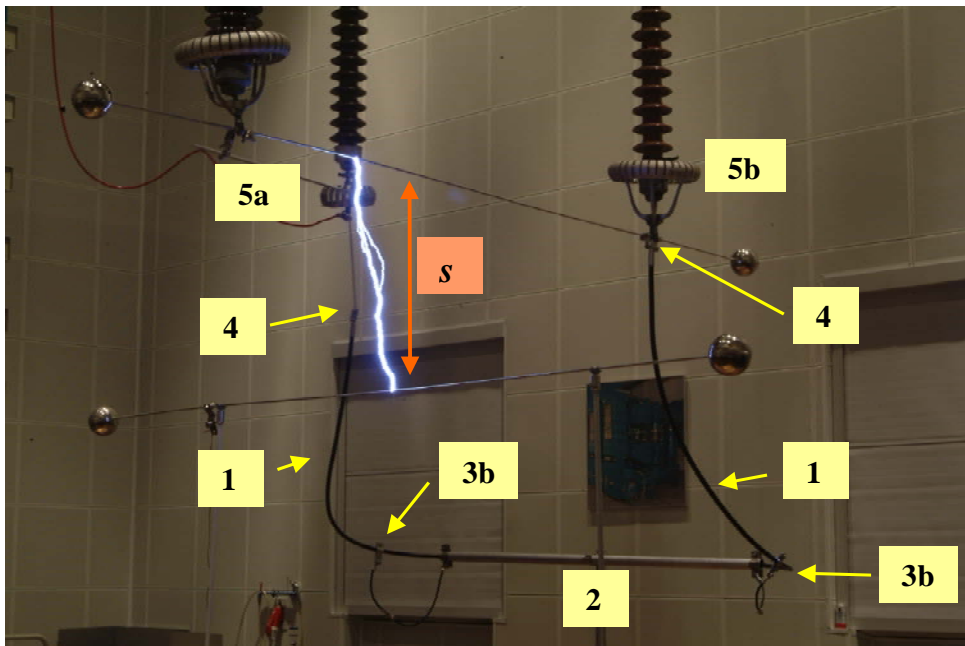


Figure 3: Test assembly, test specimen with comparison arrangement (spark gap); numbering as in Figure 2

Testing was performed with a test voltage (steep impulse 0.4/45 μ s – negative polarity). The corresponding peak value of the test voltage U_s , the time to crest T_C and the distance s of the spark gap in the comparison arrangement are indicated for each test loading in the corresponding tables.

In the following a description of one (1) complete test series each for the insulated down conductor "HVI Standard" and "HVI Light" is given.

The basic assembly is identical for both test series.

For the testing of the insulated down conductor "HVI Standard", the length of the potential control area is $l_1 = 1.5 \text{ m}$. The distance of the spark gap in the comparison arrangement is specified with $s = 0.75 \text{ m}$.

For the testing of the insulated down conductor "HVI Light", the length of the potential control area is $l_1 = 1.2 \text{ m}$. The distance of the spark gap in the comparison arrangement is specified with $s = 0.45 \text{ m}$.

The length of the metal pipe $l_2 = 2 \text{ m}$ is identical in both test series.

3. Implementation of Tests and Compilation of Results

Tests were carried out in the High voltage laboratory of the Georg-Simon-Ohm University of Applied Sciences Nuremberg on two (2) different dates and on different test series for the specimen of the insulated down conductors "HVI Standard" and "HVI Light".

3.1. Results of test series with the insulated down conductor "HVI Standard"

Test series with the insulated down conductor "HVI Standard" were implemented on 2010/07/15. Further details about the test environment see Annex 1. Test results are compiled in the following tables assorted in triplets of the same environmental conditions. One table each has been compiled for every specimen. Numbering of the specimens of the insulated down conductor "HVI Standard" is according to the scheme S0number.

Test No.	Peak value U_s in [kV]	Time to crest T_c in [μ s]	Distance VA s in [cm]	Remarks
→ S01 "HVI Standard" wet - tap water				
14287	-806	1,70	75	CA ¹
14288	-800	1,74	75	CA
14289	-789	1,83	75	CA
→ S01 "HVI Standard" wet - 5% NaCl-Solution				
14290	-785	1,87	75	CA
14291	-789	1,91	75	CA
14292	-787	1,95	75	CA

Table 1: Compilation of test results for test specimen S01 "HVI Standard"

¹ CA = sole response of the comparison arrangement (flashover of the spark gap). No significant pre- or creeping discharges noticeable.

Test No.	Peak value U_s in [kV]	Time to crest T_C in [μ s]	Distance CA s in [cm]	Remarks
→ S02 “HVI Standard“ dry				
14300	-793	1,90	75	CA
14301	-790	1,83	75	CA
14302	-790	1,88	75	CA
→ S02 “HVI Standard“ wet - 5% NaCl-Solution				
14303	-787	1,88	75	CA
14304	-787	1,82	75	CA
14305	-787	1,90	75	CA

Table 2: Compilation of test results for test specimen S02 “HVI Standard“

Test No.	Peak value U_s in [kV]	Time to crest T_C in [μ s]	Distance CA s in [cm]	Remarks
→ S03 “HVI Standard“ dry				
14317	-820	1,76	75	CA
14318	-821	1,78	75	CA
14319	-821	1,67	75	CA
→ S03 “HVI Standard“ wet - tap water				
14320	-819	1,71	75	CA
14321	-824	1,78	75	CA
14322	-821	1,69	75	CA

Table 3: Compilation of test results for test specimen S03 “HVI Standard“

Test No.	Peak value U_s in [kV]	Time to crest T_C in [μ s]	Distance CA s in [cm]	Remarks
→ S04 “HVI Standard“ dry				
14325	-815	1,79	75	CA
14326	-815	1,77	75	CA
14327	-815	1,71	75	CA

Table 4: Compilation of test results for test specimen S04 “HVI Standard“

Test No.	Peak value U_s in [kV]	Time to crest T_c in [μ s]	Distance CA s in [cm]	Remarks
→ S05 “HVI Standard“ wet - tap water				
14331	-817	1,83	75	CA
14332	-817	1,68	75	CA
14333	-816	1,78	75	CA
→ S05 “HVI Standard“ wet - 5% NaCl-Solution				
14334	-815	1,72	75	CA
14335	-816	1,86	75	CA
14336	-819	1,82	75	CA

Table 5: Compilation of test results for test specimen S05 “HVI Standard“

All tests furthermore have been evaluated by means of photos. Figures 4 to 6 for example show one photo each of one environmental condition.

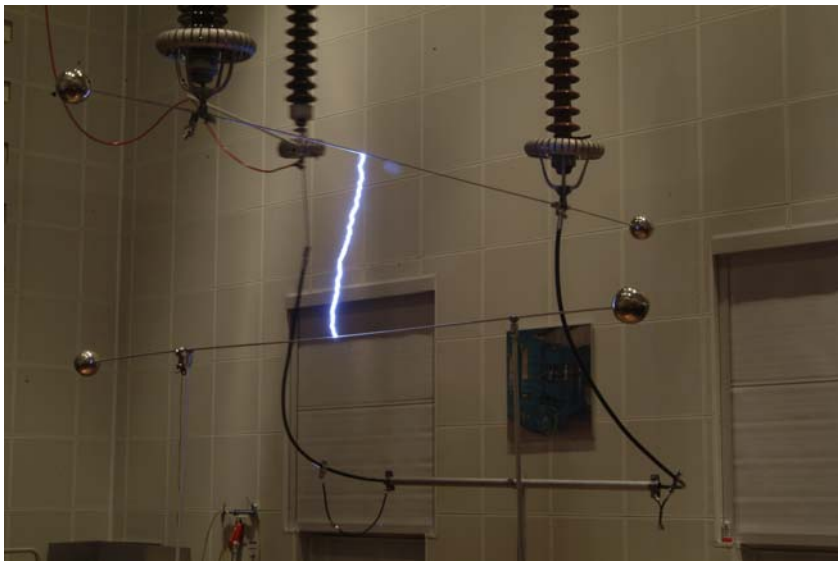


Figure 4: Photographical evaluation “HVI Standard“, dry

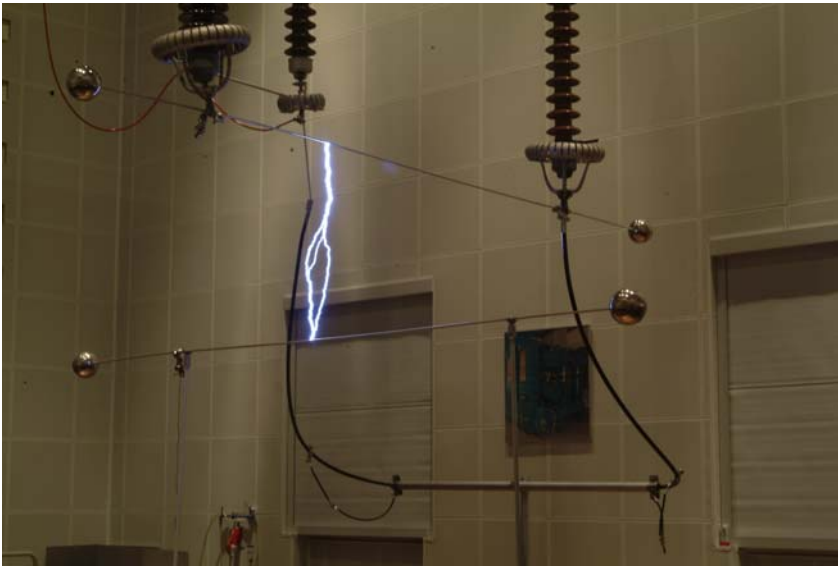


Figure 5: Photographical evaluation “HVI Standard“, wet – tap water



Figure 6: Photographical evaluation “HVI Standard“, wet – 5% NaCl-Solution

Even at worst case environmental conditions such as the wetting with 5% NaCl solution, no significant approaches of pre- or creeping discharges are noticeable at the test specimens of the insulated conductor "HVI Standard".

3.2. Results of test series with the insulated down conductor "HVI Light"

Test series with the insulated down conductor "HVI Light" were implemented on 2010/07/20. Further details about the test environment see Annex 1. Test results are compiled in the following tables assorted in triplets of the same environmental conditions. One table each has been compiled for every specimen. Numbering of the specimens of the insulated down conductor "HVI Light" is according to the scheme L0number.

Test No.	Peak value U_s in [kV]	Time to crest T_C in [μ s]	Distance CA s in [cm]	Remarks
→ L01 “HVI Light“ dry				
14351	-602	1,17	45	VA
14352	-561	1,31	45	VA
14353	-561	1,34	45	VA

Table 6: Compilation of test results for test specimen L01 “HVI Light“

Test No.	Peak value U_s in [kV]	Time to crest T_C in [μ s]	Distance CA s in [cm]	Remarks
→ L02 “HVI Light“ wet - tap water				
14357	-558	1,27	45	VA
14358	-559	1,38	45	VA
14359	-559	1,42	45	VA
→ L02 “HVI Light“ wet - 5% NaCl-Solution				
14360	-559	1,30	45	VA
14361	-558	1,35	45	VA
14362	-559	1,38	45	VA
→ L02 “HVI Light“ dry				
14363	-557	1,31	45	VA
14364	-558	1,34	45	VA
14365	-558	1,36	45	VA

Table 7: Compilation of test results for test specimen L02 “HVI Light“

Test No.	Peak value U_s in [kV]	Time to crest T_C in [μ s]	Distance CA s in [cm]	Remarks
→ L03 “HVI Light“ dry				
14366	-561	1,46	45	VA
14367	-562	1,43	45	VA
14368	-561	1,38	45	VA
→ L03 “HVI Light“ wet - tap water				
14369	-562	1,44	45	VA
14370	-561	1,32	45	VA
14371	-562	1,39	45	VA

→ L03 “HVI Light“ wet - 5% NaCl-Solution				
14372	-558	1,50	45	VA
14373	-562	1,39	45	VA
14374	-563	1,42	45	VA

Table 8: Compilation of test results for test specimen L03 “HVI Light“

Test No.	Peak value U_s in [kV]	Time to crest T_c in [μ s]	Distance CAs in [cm]	Remarks
→ L04 “HVI Light“ wet - tap water				
14376	-561	1,33	45	VA
14377	-564	1,35	45	VA
14378	-562	1,29	45	VA
→ L04 “HVI Light“ wet - 5% NaCl-Solution				
14379	-563	1,32	45	VA
14380	-561	1,29	45	VA
14381	-563	1,29	45	VA

Table 9: Compilation of test results for test specimen L04 “HVI Light“

All tests furthermore have been evaluated by means of photos. Figures 7 to 9 for example show one photo each of one environmental condition.

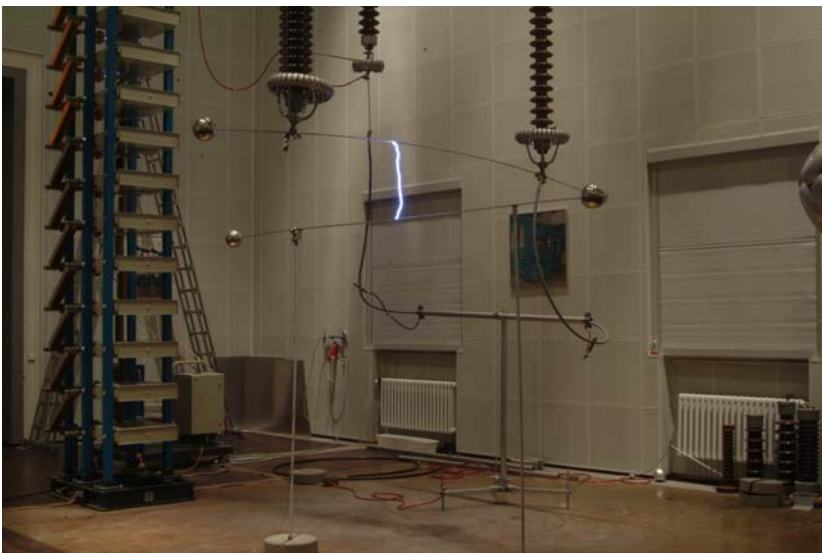


Figure 7: Photographical evaluation “HVI – Light“, dry



Figure 8: Photographical evaluation „HVI – Light“, wet – tap water



Figure 9: Photographical evaluation “HVI – Light“, wet – 5% NaCl-Solution

Even under worst case environmental conditions such as the wetting with 5% NaCl-solution, no significant approaches of pre- or creeping discharges are noticeable at the test specimen of the insulated conductor "HVI Light".

4. Summary

Within the scope of implemented tests it turned out that both of the insulated down conductors "HVI Standard" and "HVI Light" are in full compliance with the requirements described in Section 1.

Requirements are considered as met if one and the same test specimen has successfully passed at least three (3) test loads in series under equal environmental conditions. Furthermore three (3) different specimens had to be tested for each environmental condition. One performance matrix each gives a survey shown in the following (Table 10 for "HVI Standard" and Table 11 for "HVI Light").

HVI Standard	Test specimen No. S0X met requirements of		
Environmental conditions	1. Test series	2. Test series	3. Test series
dry	S02	S03	S04
wet - tap water	S01	S03	S05
wet – 5% NaCl-Solution	S01	S02	S05

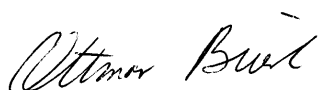
Table 10: Performance matrix for insulated down conductor “HVI Standard“

HVI light	Test specimen No. L0X met requirements of		
Environmental conditions	1. Test series	2. Test series	3. Test series
dry	L01	L02	L03
wet - tap water	L02	L03	L04
wet – 5% NaCl-Solution	L02	L03	L04

Table 11: Performance matrix for insulated down conductor “HVI Light“

As the summary shows, the test specimens usually were able to stand a significantly higher number of test loads (compared with the required three (3) test loads), so that they could be used in more than one test series. In case of all test series implemented with the insulated down conductor "HVI Standard" and "HVI Light", no significant approaches of pre- or creeping discharges were noticeable.

Aurachtal, 16. August 2010



Prof. Dr. Ottmar Beierl

Annexes, Enclosures

Annex 1 Information about the environmental test conditions

Date of test: **2010/07/15**
Place of test: High voltage laboratory Georg-Simon-Ohm University of Applied Sciences
Nuremberg
Participants: Dr. Brocke, Mr. Schöll, Mr. Seger (DEHN + SÖHNE);
Mr. Bergmann, Prof. Dr. Beierl (Ohm University)
Air pressure: 1014 hPa
Temperature: 28 °C
Rel. humidity: 51 %

Date of test: **2010/07/20**
Place of test: High voltage laboratory Georg-Simon-Ohm University of Applied Sciences
Nuremberg
Participants: Mrs. Daum, Mr. Schöll (DEHN + SÖHNE);
Mr. Bergmann, Prof. Dr. Beierl (Ohm University)
Air pressure: 1015 hPa
Temperature: 28 °C
Rel. humidity: 46 %

Annex 2 Part Nos of the used test specimens

“HVI Standard“ Part No. 819020, 819021, 819022
“HVI Light“ Part No. 819 125

Annex 3 Printed copies of the TR – AS – measurement system

(see following pages)