Influence of extreme low humidity on the dielectric strength of air insulation under critical design voltages

L. Arevalo[1], D. Wu, O. Diaz   **M. Larsson, C. Tornkvist**
ABB Power Grids – HVDC   **ABB Corporate Research**
                              Sweden

SUMMARY

The dielectric strength of external insulation depends on several parameters such as type of overvoltage stresses, geometry, location and surroundings, and the effect of the combination of atmospheric conditions such as humidity, pressure, and temperature, among others. The general understanding of the dielectric strength of air is that it decreases with increasing temperature and with the reduction of humidity, i.e., with the reduction of the water content in the air.

Usually, the site conditions where equipment is installed, are different than the standard reference conditions, i.e., temperature of 20 C, air pressure of 101.3 kPa and absolute humidity of 11 g/m^3. Also, the equipment site location might have conditions different from the normal service design conditions, e.g., maximum ambient temperature and altitude not exceeding 1000 m.o.sl. For the sake of achieving proper design and testing of high voltage apparatus, atmospheric correction procedures are recommended in the international standards to translate site or laboratory conditions to standard atmosphere conditions. These corrections are performed to temperature, humidity and atmospheric pressure.

Unfortunately, up to now, the complex process behind the effect of the atmosphere under different conditions like transient overvoltages, electric field conditions (electrode shape, gap spacing), is still not fully understood. Therefore, to perform atmospheric corrections, different empirical or semi-empirical approaches are recommended in the international standards, e.g. IEC 60060-1, IEC 60071-2, IEC 62271, etc. The parameters recommended in the standards have been validated for different electrode arrangements such as rod-plane, rod-rod, post-insulator exposed to different atmospheric conditions. However, the experiments could not cover all possible electrode configurations existing in high voltage applications. A number of experimental studies have reported inaccuracies in the application of the correction. For example, over corrections on the humidity effects for specific type of arrangements and atmospheric conditions under switching voltage impulses were reported by using IEC 60060 humidity correction factor.

The present paper is dedicated to study the atmospheric corrections used in external air insulation for extreme low humidity $0 < h/\delta < 4$ g/m^3 for various electrode configurations. Tests were performed under critical design voltages such as positive switching impulses and direct voltage DC. All tests were performed indoors in a high voltage hall with controllable humidity and temperature. Quasi-uniform and non-uniform gaps were examined. The experimental data was compared with the recommendations of IEC standard 60060-1. Experimental results indicate that under extreme low humidity conditions, correction factors overcorrect the voltage ca. 9% for switching voltage impulse stresses and 15% for DC voltage for non-uniform gap configurations. Moreover, it was observed that below certain value of h/δ, the slope of the relative humidity versus breakdown voltage trend changes, i.e., the breakdown voltage increases as the relative humidity is reduced. Based on these findings it was concluded that the actual humidity correction factors proposed in the international standards are not applicable for extreme low humidity cases.

KEYWORDS
Breakdown, discharge propagation, humidity correction, low humidity.

Liliana.Arevalo@se.abb.com

1. INTRODUCTION

The influence of humidity on the dielectric strength of external air insulation is a complicated phenomenon that has not been fully understood. International standards provide correction methods to translate testing and/or site location conditions to standard atmospheric conditions [1]. The recommended method to perform humidity correction is based on semi-empirical approximations of experimental data of tests performed to electrode arrangements type rod-plane, rod-rod and postinsulator; together with a semi-empirical relation of the breakdown voltage at standard atmospheric conditions and the mean electric field gradient for positive streamer propagation. Moreover, the humidity correction was correlated with the relative air pressure to consider that absolute humidity corresponds to a constant partial pressure of water vapor regardless of the changes in air partial pressure which occur with changes of air density [2]. According to [2], the procedure is successful to represent corrections under positive switching and lightning impulses. For DC voltage, it is claimed that the procedure can be applied in a limited range of gap spacings and humidity, with unexpected variations for very small and very large gaps.

This manuscript is dedicated to analysing the effect of extreme low humidity on the breakdown process of electrode arrangements such as rod-plane gap, toroid-plane, and sphere-plane. The test results are compared with the corrections recommended by IEC standard 60060 [1]. The results indicate that the standard fails to reproduce the breakdown process at extreme low humidity conditions and overcorrections of 9% and 15% could be obtained for positive switching voltage impulses and DC voltage at extreme low humidity conditions, respectively.

2. TEST METHODS

Two test campaigns [3, 4] are gathered and studied in this paper. The tests were performed under standard 250/2500 µs positive switching impulses and under positive DC voltage. Tests were done at different humidity ranging between $0<h/\delta<11$ g/m^3. Different configurations were tested: rod-plane, sphere-plane and toroid-plane. Interelectrode gap distances of 600 mm, 1 m and 2 m were tested under switching impulse stress. For DC tests, all geometries were tested at a gap distance of 1 m. The electric field uniformity of the arrangements is estimated by the uniformity factor $\eta=E_{max}/E_{mean}$. Where $\eta > 4$ is considered as extremely non-uniform and factors in the range $2< \eta <4$ are considered the transition region between uniform and weakly non-uniform field. All tests were carried out indoors in a high voltage hall with controllable humidity and temperature. Specific details of the tests are provided in the following sections and in references [3, 4].

For the switching impulse test, the voltage level of the 50% breakdown probability, U_{50}, was obtained for each configuration using the well-known up-and-down method. A total of 30 individual switching impulses were applied for each test with at least 15 breakdowns. The voltage level of 50% breakdown probability U_{50} and the standard deviation of the test σ were determined. During the test, the applied voltage and the waveform of the voltage were recorded. Still-camera and fast-camera were used to record the trajectories of the discharges.

For the DC voltage tests, the average breakdown voltage level, $U_{breakdown}$, was obtained of 10 breakdown voltage tests. The applied voltage was increased slowly until breakdown occurs. Starting from a voltage not higher than 75% of the expected breakdown voltage, the voltage application was ramped up at a rate of ca. 2% of the breakdown voltage per second, following IEC 60060 [1] recommendation. The applied voltage and the waveform of the voltage were recorded. Specific details of the test are provided in the following sections and in reference [5].

3. TEST RESULTS

Tables 1 to 6 summarize the test results, atmospheric conditions and the corresponding correction following the recommendations of IEC 60060 [1]. The symbols P, T, h, U_{50}, σ, $U_{50corrected}$, k_d and k_h are used to represent the pressure, temperature, humidity, 50% breakdown voltage, standard deviation, 50% breakdown voltage corrected according to IEC60060, atmospheric pressure correction factor and humidity correction factor,

respectively. Notice that the final column of each table identified with % symbol indicates the percentage of difference between the corrected value and the values measured at standard atmospheric conditions, values at standard conditions are reported in [3, 5, 6]

3.1 Rod-plane gap tests

A 20 mm diameter rod with half sphere tip was used for distance of 600 mm. For 1 and 2 m gap distance a 10 mm hemispherical tip rod was used.

Table 1: Switching impulse test. Rod-plane.

Gap length	P [mbar]	T [C]	h [g/m³]	U_{50} [kV]	σ [%]	$U_{50corrected}$ [kV]	k_d	k_h	%
600mm	982	20,4	1,1	279	2,4	320	0,96	0,90	2,5
η = 3.5	978	55	1.1	242	4.1	314.2	0.85	0.90	0.0
1m	1009	20.4	0.5	436.3	2.2	490	0.99	0.90	7.5
η = 117	1004	21.2	2.1	419.0	2.5	460.6	0.99	0.92	1.1
2m	1007	20.4	0.5	722.6	2.1	780.7	0.99	0.93	2.7
η > 117	1004	21.8	1.8	733.6	1.4	790	0.99	0.94	3.9

Table 2 DC voltage. Rod-plane, gap 1 m, η=117

P [mbar]	T [C]	h [g/m³]	U_{50DC} [kV]	σ [%]	$U_{50DCcorrected}$ [kV]	k_d	k_h	%
1038	21,9	0.7	475.9	0.7	563.9	1.01	0.83	7.11
1038	22,5	1.5	468.1	1.2	546.7	1.01	0.85	3.85
1038	22,4	2.2	463.0	0.8	532.8	1.01	0.86	1.21
1038	22,6	3.0	467.3	0.7	529.3	1.01	0.87	0.53

3.2 Sphere - plane gap tests

For switching impulse voltage tests, 150 mm diameter sphere at 600mm gap distance was used and a 250 mm diameter sphere for tests at 1 and 2 m. For DC voltage tests a sphere of 250 mm diameter was used.

Table 3: Switching impulse test. Sphere-plane.

Gap config.	P [mbar]	T [C]	h [g/m³]	U_{50} [kV]	σ [%]	$U_{50corrected}$ [kV]	k_d	k_h	%
Sphere 150mm; gap	967	19.5	1.0	267	1.1	311.3	0.95	0.90	0.0
= 600mm; η = 7.9	966	55	1.3	237	1.4	310.5	0.84	0.91	0.0
Sphere 250mm; gap	1006	20.5	0.6	728.1	1.1	757.6	0.99	0.97	-0.2
= 1m; η = 9	1006	21.1	0.9	730.6	1.3	760.9	0.99	0.97	0.2
Sphere 250mm; gap	1007	20.5	0.5	849	1.5	948.7	0.99	0.90	2.5
= 2m; η = 9	1008	21.6	0.9	845	1.4	942	0.99	0.91	1.8

Table 4 DC voltage. Sphere 250mm – plane. Gap 1 m, $η$=7.15

P [mbar]	T [C]	h [g/m³]	U_{50DC} [kV]	σ [%]	$U_{50DCcorrected}$ [kV]	k_d	k_h	%
1019	19,8	0.4	448.2	1.1	540.4	1.00	0.83	12.35
1019	19,7	2.0	445.0	0.9	518.8	1.00	0.86	7.84
1019	20,9	2.7	448.2	0.8	516.9	1.00	0.87	7.46

3.3 Toroid - plane gap tests

For switching impulse voltage tests, three toroid dimensions were tested. For gap distances of 600 mm, toroid with dimensions: 350 mm outer diameter and tube diameter of 100 mm (350/100), and 425 mm outer diameter and 75 mm tube diameter (425/75) were used. For distances of 1 and 2 m, the toroid dimensions were outer diameter 600 mm and tube diameter 100 mm (600/100). For DC voltage tests, two different toroids were tested at 1 m gap distance: 600/100 and 320/60.

Table 5: Switching impulse test. Toroid 350/100 mm – plane. Gap 600 mm, $η$ = 5.9

Gap config.	P [mbar]	T [C]	h [g/m³]	U_{50} [kV]	σ [%]	$U_{50corrected}$ [kV]	k_d	k_h	%
Toroid 350/100; gap	933	20	0.85	354	4.6	385.9	0.92	1.0	9.0
= 600mm; η = 5.9	969	55.6	0.9	312	1.7	369.6	0.84	1.0	4.4
Toroid 425/75; gap = 600mm; η = 6.9	1000	20.2	0.8	339	2.1	345.0	0.98	1.00	2.4
	991	19.8	4.0	335	1.0	343.5	0.98	1.00	1.9
	1003	54.5	1.0	303	1.1	345.6	0.88	1.00	2.54
Toroid 600/100; gap = 1m; η = 8.4	1005	21.2	0.39	485.2	1.1	551.6	0.98	0.89	8.4
	1005	21.4	0.94	490.9	0.8	555.0	0.98	0.90	9.1
	1005	21.4	2.04	492.4	0.6	549.9	0.98	0.91	8.1
	1001	21.1	3.06	498.8	0.7	552.4	0.98	0.92	8.6
Toroid 600/100; gap	1033	21.7	0.63	522.5	1.0	611.4	1.01	0.85	15.83

= 2m; η = 12	1033	22.2	1.00	520.5	0.9	608.6	1.01	0.85	15.30
	1033	22.5	1.97	521.0	1.0	602.8	1.01	0.86	14.22
	1033	22.6	3.47	530.2	0.4	597.5	1.01	0.88	13.20

Table 6: DC voltage. Toroid 320/60 mm – plane. Gap 1 m, $\eta = 8.15$

P [mbar]	T [C]	h [g/m³]	U_{50} [kV]	σ [%]	$U_{50corrected}$ [kV]	k_d	k_h	%
1020	19.6	0.37	459.7	3.7	553.9	1.00	0.83	15.71
1020	20.6	1.03	499.9	1.1	595.8	1.00	0.84	24.45
1019	21.0	2.03	451.6	0.9	527.9	1.00	0.86	10.27
1019	21.3	2.98	452.3	0.7	519.0	1.00	0.87	8.41

4.   DISCUSSION

According to IEC60060 standards [1], the humidity correction factor k_2 depends on a humidity factor k and an exponent w, as described in equation (1). The k is a correlation factor between the breakdown voltage at any humidity U_{50}, respect to the breakdown voltage at standard humidity $h = 11$ g/m³ to relative density δ, $U_{50,0}$ as described in equation (2) [2].

$$k_2 = k^w \quad (1)$$

$$k = \frac{U_{50}}{U_{50,0}} \qquad (2)$$

The k factor depends on the type of test voltage; equation (3) describes the k factor for DC voltage stress and equation (4) corresponds to the k value for impulses, both equations in function of the ratio of absolute humidity to relative density:

$$k = 1 + 0.014 \cdot \left(\frac{h}{\delta} - 11\right) - 0.00022 \cdot \left(\frac{h}{\delta} - 11\right)^2 \quad (3) \qquad k = 1 + 0.010 \cdot \left(\frac{h}{\delta} - 11\right) \quad (4)$$

The tests are analyzed based on these two parameters; the k factor is calculated for each arrangement, based on equation (2) and compared with k recommended at IEC standards, equations (3) and (4) respect to h/δ relation.

4.1 DC voltage tests

The tables for DC voltage show an overcorrection between 7% for rod-plane, up to 12% for sphere-plane and 15 to 24% toroid-plane when the standard correction recommendation is applied to tests under extreme low humidity conditions. Indicating that the correction recommended by the standard adds large margins to direct voltage DC at extreme low humidity conditions, i.e., leading to high testing voltages for equipment and high voltage requirements to design insulation.

Figure 1 presents the k factor as function of absolute humidity h to relative air density δ. It shows that only arrangements of the type rod-plane gap follow the standard recommendation in a range $3 < h/\delta < 10$ g/m³. For other type of arrangements such as sphere-plane and toroid-plane, the k_2 correction factor provided by IEC standards [1] does not represent the real relation between breakdown voltage at any humidity vs. the breakdown voltage at standard atmospheric conditions. It is evident that the tendency of the figure k vs. h/δ changes depending on the uniformity factor of the arrangement η. Therefore, a generalized k factor used for all kind of geometries might not be applicable and introduce significant errors in the humidity correction. In the worst case, a difference of 24.5% is obtained between k of IEC 60060 [1] and k calculated based on measurements.

For extreme low humidity, i.e., $h/\delta < 2$ g/m³, the slope of the relation k vs. h/δ changes to the opposite: the lower the relation h/δ, the higher the breakdown voltage. This behavior is noticeable in non-uniform arrangements such as rod-plane gap $\eta = 117$, sphere-plane $\eta = 7.15$ and toroid-plane (320/60) $\eta = 8.15$. For quasi-uniform arrangements like toroid-plane 600/100 $\eta = 5.34$, the change of slope is not significant and an almost constant linear behavior is

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observed. It is important to highlight that this type of behavior was reported by other authors [2, 7] for gaps type rod-rod and rod-plane at gap distances shorter than 0.8 m. According to [2, 8] this behavior is a property of short gaps at low humidity with glow pre-discharge phenomena and no streamer.
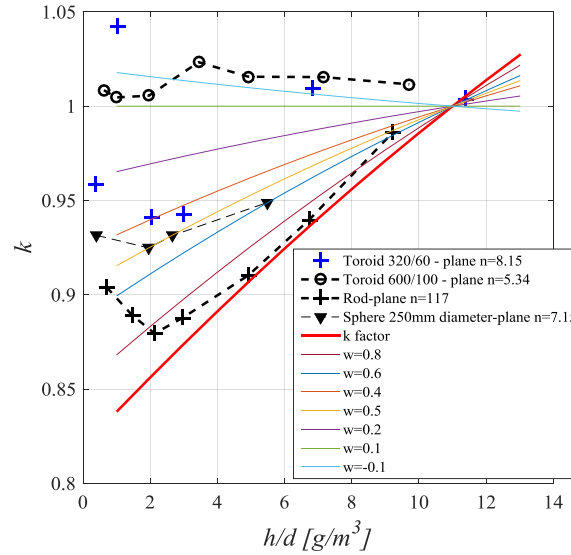
Figure 1. k_2 factor vs. h/δ under DC voltage for different configurations compared with IEC 60060 recommended k and w.

Figure 2 and 3 present the images of discharge path obtained for rod-plane gap and toroid-plane gap for two different humidities respectively. Extreme low humidity discharge process is compared with discharge at humidity higher than 2 g/m^3, humidity boundary where a change of trend of the breakdown voltage is observed. Figures show that the discharge process includes the streamer inception and the propagation of a luminous channel and in front of it, a less bright streamer region. This discharge propagation process replicate the well-known streamer-leader propagation discharge. Based on this evidence, it can be concluded that the increment of breakdown voltage at extreme low humidity is observed not only for glow pre-breakdown process as previous experimental evidence has shown [2, 7, 8], but also at gap distances were streamer-leader breakdown can be observed.
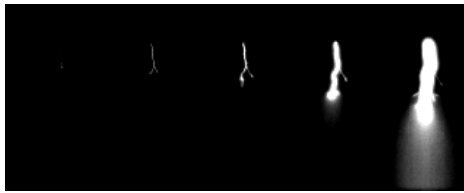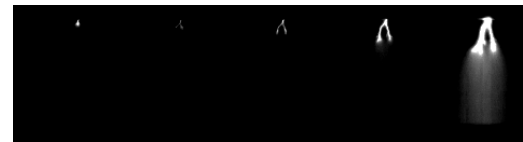

Figure 2. Photographs of discharge propagation for rod-plane 1m gap. a) H=0.71 g/m^3 time elapse 10.21μs.

b) Humidity H=3 g/m^3 time elapse 6.39μs
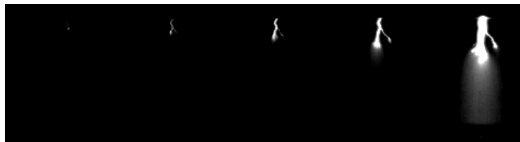
Figure 3. Photographs of discharge propagation for a toroid 320/60 – plane 1 m gap. (a) H=0.4 g/m^3 time elapse 12μs

(b) H = 6.8 g/m^3 time elapse 8.5μs.

The pictures demonstrate that the development process of the discharge takes longer time for extreme low humidity conditions compared with humidity higher than 2 g/m^3 for same configuration. One can hypothesize that due to extreme low humidity conditions, the propagation of the discharge is affected and propagation velocity of the discharge is reduced. The electrical breakdown of air is mediated by an increase in the electron concentration in air and the process that lead the increase in electron

concentration is the ionization processes. From the electrical discharge physics point of view, it can be inferred that at very low humidity conditions the process of elastic and inelastic collisions of electrons is reduced, i.e., the mobility of electrons in the air media is diminished compared to standard atmospheric conditions. The background electric field exerts a force on the propagation of particles, but the drift velocity of the particles is not high enough to help the continuous propagation of the discharge, i.e., the further ionization of neutrals. More detailed reasons could be found on the electron affinity of atoms in air under extreme low humidity conditions and attachment frequency of air under extreme low humidity conditions.

Moreover, it is known that the air critical electric field for positive streamer propagation changes with temperature, air density and with humidity [9]. The critical electric field for positive streamer propagation in air grows from 470 kV/m at humidity of 3 g/m^3 to 560 kV at 18 g/m^3. Therefore, it could be assumed that at extreme low humidity conditions, the critical electric field required for streamer propagation increases compared with the one required for 3 g/m^3. More detailed understanding from the discharge physics is required in order to describe fully the breakdown phenomena and dielectric strength of air at extreme low humidity conditions. However, it is possible to conclude that under DC voltage stress, the dielectric strength at extreme low humidity conditions is not reduced but instead increases compared with dielectric stress of same arrangement at humidity conditions higher than 3 g/m^3.

4.2 Positive switching impulse tests

The results summarized in the tables under positive switching impulses indicate an overcorrection of 7% for rod-plane, 2.5% for sphere-plane and 9% for toroid-plane for extreme low humidity conditions. It demonstrates that the recommendations of humidity corrections provided by the standards will require higher testing voltage levels and/or an insulation design for higher voltages than the voltage really required for such arrangement and humidity conditions.
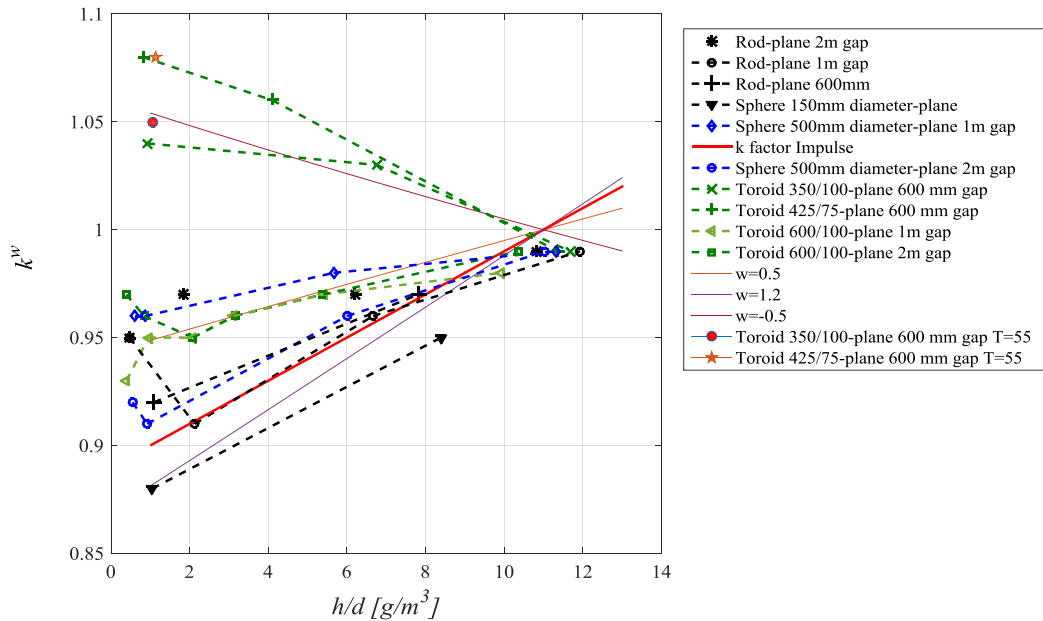

Figure 4. k_2 factor vs. h/δ under switching impulse voltage stress for different configurations compared with IEC 60060 recommended k and w.

The relation of the correction factor k_2 vs. h/δ for switching impulse voltage tests is presented in Figure 4. It shows that only rod-plane 1 m gap follows the correction factor recommended by the standard for relations of h/δ higher than 2 g/m^3, for lower relative humidity the slope of the curve changes indicating an increment of the breakdown voltage. For other configurations, it is evident that the correction recommended by the standard [1] does not represent the real behavior of the breakdown voltage at different relative humidity conditions.

For extreme low humidity $h/\delta < 2$ g/m^3, a change of the slope of the relation of breakdown voltage and relative humidity is observed. A similar behavior was observed for similar geometry arrangements under direct voltage DC stress. This behavior was found for gaps of 1 and 2 m, for all type of configurations rod-plane, sphere-plane and toroid-plane. For 600 mm gaps the slope does not change considerably: results show an increase of the breakdown voltage with the reduction of h/δ relation.

The current at ground level was measured for different tests and fast camera videos were taken to analyze the discharge process and correlate current and luminosity observations. Figure 5 shows the current for the rod-plane arrangements at different humidity content. Some pulses on the current measurement are noise signal originated by the laboratory setup, therefore a contrast with the camera observations was required to identify the different stages of the discharge.
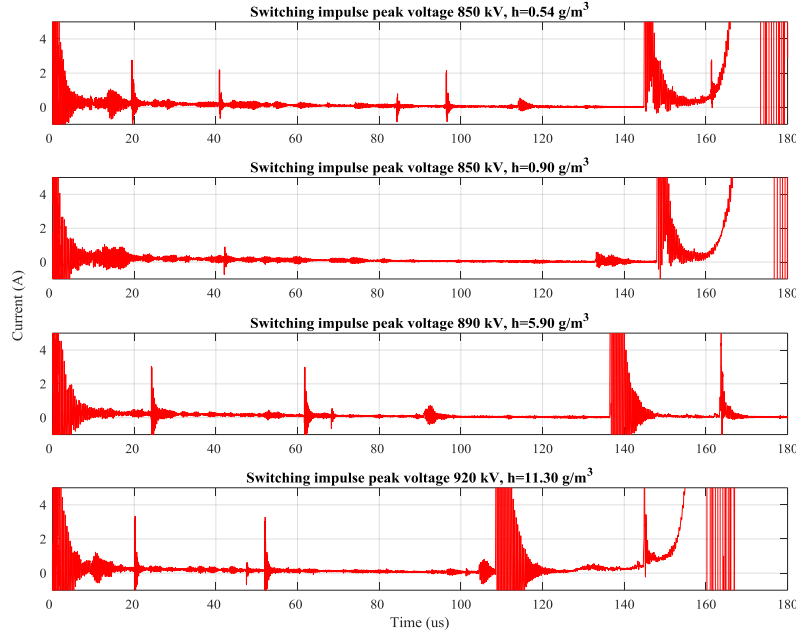
Figure 5. Current measured at ground level for different humidity for sphere-plane 2 m gap under positive switching impulse voltage stress.

The analysis of this paper is mainly dedicated to large gaps, as humidity studies in long gaps have been mainly concentrated on the effect of time to crest [2] and for the knowledge of the authors there are no reports dedicated to extreme low humidity effect for large gaps. By reviewing the different current registers and images from the propagation of the discharge, parameters such as streamer-to-leader transition time and time to breakdown can be estimated. Tables 7 and 8 summarize detailed data of the discharge path, obtained for gaps of 2 m. The values reported in the tables are average values from all breakdown measurement observations and their standard deviations close to 15%.

Table 7: Discharge propagation data.

Sphere 250 mm diameter – plane gap 2m η=7.15			*Toroid 600/100 mm – plane. Gap 2 m. η=5.34*		
h [g/m³]	*Streamer-to-leader transition [µs]*	*Time to breakdown [µs]*	*h [g/m³]*	*Streamer-to-leader transition [µs]*	*Time to breakdown [µs]*
0.54	159.72	192.89	0.39	62.89	133.50
0.91	159.67	185.25	0.83	69.29	142.36
5.96	142.48	180.46	3.09	65.59	136.29
10.97	115.65	159.57	5.28	65.42	133.26
			10.15	62.04	126.72

Table 8: Discharge propagation data. Rod-plane, gap 2 m, η > 117

h [g/m3]	*Streamer inception [µs]*	*Streamer to leader transition [µs]*	*Time to breakdown [µs]*
0.45	12,24	35,1	126,8
1.80	15,02	27,7	120,3
6.12	10,05	23,3	116,1
10.68	9,37	21,9	120,6

For the rod-to-plane electrode arrangement, it was easily recognizable from the fast camera records all the stages of the full electrical discharge, as it can be observed in Figure 6. It initiates with the streamer inception (t=18 μs), followed by a low activity/radiation 'dark' period (between 18-30 μs); then it is continued with the streamer to leader transition (31 μs), afterwards comes the leader propagation with the streamer leader in front of the leader tip (31-108 μs) and finally reaching the breakdown stage.

| 18 | 22 | 31 | 37 | 43 | 45 | 51 | 55 | 60 | 66 | 77 | 83 | 88 | 92 | 97 | 102 | 105 | 108 |
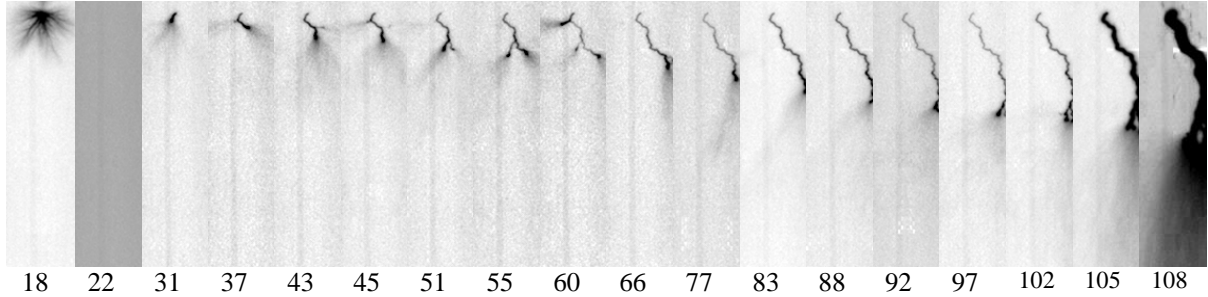
Figure 6. Negative of fast camera frames recorded for the 2m rod-to-plane electrode arrangement tested with positive switching voltage impulses in air at h=1.8 g/m³. Time stamps in [μs]

Based on the collected data for gaps of 2 m it is possible to observe that the discharge inception and propagation changes with the relative humidity. For extreme low humidity conditions, it is evident that the streamer-to-leader transition time occurs later compared with humidity conditions higher than 3 g/m³. For sphere-plane arrangements the time difference between the streamer-to-leader transition at low humidity and standard atmospheric conditions is ca. 45μs; for toroid-plane this difference is ca. 7μs, and for rod-plane ca. 13 μs. This result could be an indication that humidity plays a major role in the initial part of the discharge, i.e., streamer inception and propagation, but less significant role once a leader is incepted. The time differences between different electrode arrangements at very low humidity conditions are mainly due to background electric field conditions.

The lapse time between leader inception and breakdown at very low humidity conditions vs. standard atmospheric conditions shows a variation of ca.11μs for the case of a sphere-plane arrangement, 5μs for toroid-plane arrangement and 7μs for rod-plane. One can hypothesize that the effect of extreme low humidity in the leader propagation variates with the gap uniformity: the more quasi-uniform the gap is, lesser is the effect of humidity on the leader propagation process.

From the exact event times, it can be seen like the initial events, which are dependent on the high electric field at the tip of the rod, tend to occur later for the lower humidity, as it is the case for the streamer inception and the streamer-to-leader transition. Compared to the leader propagation, where the discharge propagates itself into regions with lower background electric fields, the breakdown time and the vertical propagation velocity are not strongly affected by the humidity variation.

The discharge observations and current measurements performed to the tests for different arrangements at extreme low humidity conditions under switching impulse stress strength the hypothesis of the effect of extreme low humidity on the initial stage of the discharge, ionization process and streamer propagation process, provided to direct current voltage stress:
  - At extreme low humidity conditions the ionization process is not as effective as it is under normal humidity conditions. Less elastic and inelastic collisions might occur and therefore, the drift velocity of the particles is reduced and therefore less molecules energy is available to provide a continuous propagation of the initial process of the discharge.
  - The critical electric field required for the streamer propagation is higher than the one required at humidity higher than 3 g/m³.

5. CONCLUSIONS
It was demonstrated that atmospheric corrections recommended by international standard IEC60060 for switching impulses and DC voltage at extreme low humidity conditions *h/δ*

(lower than 2 g/m^3) are not appropriate and shall not be followed as they do not represent the real phenomena of the discharge. It may be necessary to divide the correction into two parts: one part for humidity lower than 2 or 3 g/m^3 and another part for humidity between 2 or 3$<h/\delta$ <11 g/m^3. The division region could be around 2 to 3 g/m^3.

Experimental tests proved that at very low humidity conditions the dielectric strength of air of different gap configurations increases under positive switching impulses and positive direct current voltage. A change of slope of the relation h/δ vs. breakdown voltage relation is observed at humidity $h/\delta < 2$ g/m^3. Therefore, it is not recommended to perform humidity corrections for very low humidity conditions.

Based on current measurements and fast-camera videos hypothesis regarding the discharge processes at low humidity conditions are proposed; such as, that ionization processes are affected and critical electric field for streamer propagation required is higher than under normal standard conditions. In order to prove such hypothesis and propose a humidity correction for very low humidity conditions, additional laboratory work and deeper understanding of electrical discharge physics is required.

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