Atmospheric and altitude correction methods for air gaps and clean insulators – corrections for short gaps under DC and application difficulties

J. RICKMANN[1*], D. TABAKOVIC[2], C. NYAMUPANGEDENGU[3], N. PARUS[4], D. WU[5] and R. DIAZ[6]

[1]Phenix Technologies, Accident, MD 21520, USA
[2]Meramec, Hubbel Power Systems, Cuba, MO, 65453, USA
[3]University of the Witwatersrand, Johannesburg, P. Bag 3, Wits 2050, South Africa
[4]ESKOM Holdings SOC Ltd, Johannesburg, South Africa
[5]ABB, 771 80 Ludvika, Sweden
[6]University of Tucuman, Tucuman, Argentina

Abstract

The dielectric strength of air gaps is affected by air density, humidity and temperature. In order to normalize external insulation strength of power equipment under different conditions, such effects need to be taken into account when external insulation is designed and tested. There are three main applications for atmospheric and altitude corrections: insulation coordination, equipment design and equipment testing. In insulation coordination standards such as in the IEC, the first 1000 m in altitude are included in the recommended voltage levels. In the design of equipment for altitudes higher than 1000 m, atmospheric correction factors exist and must be applied since the conditions at the location of service and in the laboratory where the equipment is tested may be different. This paper presents the continued work of Cigré WG D1.50 and is a continuation of the contributions to the 18th International Symposium on High Voltage Engineering in 2013 in Seoul, South Korea and the 19th International Symposium on High Voltage Engineering in 2015 in Pilsen, Czech Republic. It presents some typical rod-plane short gap test data under DC voltage at different locations with altitudes of up to 1880 m and shows them in relation to the correction curves in IEC 60060-1 (exponent m in relation to factor g). These new test results combined with the results which were the base for the current correction methods could provide the basis for formulating or revising atmospheric and altitude correction methods for short gaps under DC. A possible alternative correction method (by Calva) is also explored in comparison with the IEC method [3].

1. Introduction

The dielectric strength of air gaps is affected by air density, humidity and temperature. In order to normalize external insulation strength of power equipment under different conditions, such effects need to be taken into account when external insulation is designed and tested.

Since Peek's initial work [1], there have been successive progressive developments on the altitude and atmospheric correction methods. In that regard, currently, one of the most used standardised procedures is the IEC60060-1 [2]. However, as widely discussed in the literature, some accuracy shortfalls in the standards have been identified. The challenges include;

i. Limitations in applications of the correction factors for altitudes greater than 1800 meters above sea level (m.a.s.l.). The test data that forms the base of the current correction methods were from test sites less than 1800 m.a.s.l..

ii. The existing correction methods are based on the assumption that there is a linear variation of the streamer channel average electric field as a function of altitude (air pressure).

iii. It has also been argued that the test data on which the existing correction methods are based did not include enough direct current (DC) voltage cases such that the

*Rickmann.Johannes@gmail.com

correction methods for DC voltage could be different [3]. Furthermore, the existing correction methods do not clearly differentiate effects of DC voltage polarities.

iv. It has also been argued that the test data used to determine the *m* and *w* curves was largely for large gaps (greater than 1 m). For smaller gaps therefore, the correction factors could be different especially given that the breakdown mechanisms in short gaps are known to be different from those of long gaps.

Among the work being tackled by the Cigré WG D1.50 is the collection of new data including from tests at altitudes higher than 1800 m.a.s.l. and also of DC voltage. Together with the old data that forms the base for the current correction methods, the updated databases would then be analysed to determine whether it would be necessary to formulate new or modify the existing atmospheric and altitude correction methods including for short gaps under DC voltage.

There are three main applications for atmospheric and altitude correction methods: insulation coordination, equipment design and equipment testing. In insulation coordination, the first 1000 m in altitude are included in the recommended voltage levels [4]. In the design of equipment for higher altitudes than 1000 m atmospheric correction factors have to be applied directly. The present paper discusses the challenges related to the disharmony and inadequacies among the existing correction methods as a continuation of similar discussions in the previous articles on the Cigré D1.50 related work [5]. Some of the new experimental test data is then presented on short gaps under DC voltage and analysed comparatively using the IEC60060-1 (2010) [2] and the Calva methods [3]. The comparative accuracies are discussed together with possible improvements.

2. Application difficulties of atmospheric and altitude correction methods

Atmospheric and altitude corrections are applied for different purposes as outlined above. Each application uses a different method resulting in different correction factors for the same atmospheric condition. It is important to note that the exponents *m* used in the different methods are also defined and derived differently. For a more in depth discussion of the application difficulties we refer to [5].

2.1 Insulation Coordination

In insulation coordination (IEC 60071-2 [6]) an altitude correction for the coordination withstand voltages is applied if equipment is being placed at an altitude higher than sea level. A simplification of the correction process is applied by considering only the altitude or air pressure, humidity and temperature are considered to be cancelling each other.

$$k = e^{m\left(\frac{H}{8150}\right)} \qquad (1)$$

Where: H is in m and *m* defined differently for the different voltages (LI, SI, AC). In the case of SI, *m* is dependent on the voltage value and gap geometry.

2.2 Equipment Design

At the preliminary design stage, as part of the design process, engineers would need to get some idea on the voltage levels over the external insulation at the given application conditions, e.g. higher altitude. However, at this stage only the required voltage levels at sea level may be available.

Some apparatus standards like IEC 61869-1 [7] define a modified correction factor (2) for installations at altitudes higher than 1000 m. The required withstand voltage at the service altitude is to be multiplied with this factor to determine the necessary arcing distance under the standardized reference atmospheric conditions.

$$\mathrm{k} = \mathrm{e}^{\mathrm{m}\left(\frac{\mathrm{H}-1000}{8150}\right)} \qquad (2)$$

The first 1000 m are excluded since these are considered already included in the standardized rated withstand voltages of the apparatus.

2.3 Laboratory Tests

Laboratory tests can be separated in two main groups, withstand tests for apparatus, and breakdown tests of external insulation. The current correction factors for both applications are based on breakdown tests with 50% breakdown probability U_{50}.

In laboratory testing atmospheric corrections are applied to two different applications:

- Correction of the disruptive discharge voltage at given atmospheric conditions to the voltage which would have been obtained at standard reference atmospheric conditions (standard procedure)
- Correction of a specified voltage at standard reference to the equivalent value under test conditions (converse procedure)

2.3.1 Withstand Tests

Withstand tests are widely used for routine tests, type tests, sample tests and other tests in which no breakdown or very few breakdowns of the self-restoring insulation of the apparatus are permitted. Test voltages of various waveforms are often specified based on the results of the system requirement and over-voltage studies. Test safety factors will be added specifically for each type of high-voltage apparatus. Atmospheric corrections may need to be applied for external insulation depending on the type of applications and the location of the test in relation to the service altitude.

An HV apparatus is designed to fulfil various requirements, such as, operative function, insulation, thermal requirement, safety clearances as well as mechanical strength. The final external design may not be determined by the requirement on external insulation, i.e., by the required test voltage. Even if it is the requirement on external insulation that determines the design of the external form, it is often that only one of the voltage waveform is decisive (dimensioning).

However, the principle of atmospheric corrections in testing is based on the mean breakdown-field, such as the so called “G factor method”, as defined in [2] (E_b). If the external form of the apparatus was determined by other requirement instead of the required test voltage, or, just by one of the waveforms, the direct division of the test voltage, U_T and the external length, L, may not be equal to the mean breakdown-field of this specific design, i.e.:

$$U_T/L \neq E_b = U_b/d \qquad (3)$$

Therefore, the outcome of the correction may not be justified by this correction principle. In these cases, the correction method defined in IEC60071-2 [6] may be advantageous since it requires only the withstand voltage. In this way, actually, the correction is made on a U_T/d relationship where $d \neq L$. The justification of making correction in this way could be further discussed.

2.3.2 Insulation breakdown tests

To find more exactly the withstand level of an insulation design, tests with a reasonable number of insulation breakdowns are necessary. Test to obtain the voltage level that is of 50% breakdown probability is the most effective approach [2]. This is often used on the test object that consists of only self-restoring external insulation. Through such tests, the mean breakdown-field will be obtained. The application of the atmospheric correction based on mean breakdown-field, as given in IEC60060-1 [2], becomes more accurate.

Even with U_{50} obtained, there are still some uncertainties on how to make corrections. One of those is the application range for relative air density of the recommended curves, e.g. in [2], given in the standard today, [8],[9]. The other uncertainty is in those cases when the discharge trajectories are of significant differences in lengths and directions during the tests. This is an issue especially related to test under EHV and UHV voltage levels. Furthermore, for rain tests, it is not clear how the air density correction should be applied.

2.4 Expectation on the correction method

As outlined above there are different needs for the application of atmospheric corrections leading to different requirements. One method would be advantageous but the need for simplifications in insulation coordination and equipment design due to the lack of availability of all atmospheric data would result in unnecessary errors in the case of testing where all atmospheric data is available. It seems to be better to have two approaches, one for insulation coordination and equipment design and one for laboratory tests, like the division in the current situation between [6] and [2]. However, both approaches should arrive at the same outcome, unlike the current situation. Currently, such division is confused by statements in different standards. The method given in [2] has also been used for withstand tests.

2.4.1 Data regression

Large amount of old data and some new data are available and have been collected by the D1.50 Working Group [10]. New regressions of these data could be made with different relationships. However, since these data involve large discrepancies, a suitable approach needs to be identified on how to do such a work. Should the regression follow the most conservative trend or the average level? It is expected that a data regression with insulation distance as the main variable may lead to an easier to use correction, even though a correction with voltage as the main variable is still necessary.

2.4.2 Altitude level included

The altitude application range needs to extend to 5000 m, i.e., a lower air density than that at 2000 m. It is not expected that the effects of air density on discharges will change significantly within this range. For very small gaps in the millimetre and centimetre range, application up to 20,000 m has been specified [11]. Other possible effects related to high altitude, e.g., possible higher effects of cosmic radiation and extreme low humidity, should not be included in the air density correction, but may affect the extension of the correction method beyond 2000 m.

2.4.3 Type of insulation/gap layout

Since the correction is strongly influenced by the parameters listed above, it could make the correction more accurate and easier to understand if separation is made for different gap uniformity, gap length, and/or gap factors, similar to that in [6]. Other separation could be the cases with different interface conditions such as insulators in wet or dry conditions and in combination with AC, DC, and SI.

2.4.4 Humidity effects

To include all effects of different parameters into *w* is almost impossible. It seems that more confusion was generated instead. The way humidity influences discharges is different in comparison to air density. Such differences could not be covered just with different *w* values. Here the separation of various combinations of parameters should also be made. This would follow the older edition of IEC 60-1 (1973) [12].

3. Some new test data on short gaps at DC

3.1 General on short voltage gap definition and gap size categorisation philosophies

Traditionally, the long gaps were considered those having an electrode distance in the range of 2 m and above (typically high voltage transmission systems, rated 225 kV and above. The dielectric behavior of these long gaps, is pretty much well documented. This however is not the case with short gaps. Despite the fact that many use long/short gaps terminology, there is no clear nor distinctive definition/criterion on the gap size, characteristics, breakdown influence, etc. In fact, this subject automatically causes polarized opinions, where the gap size is still debatable among the engineering community. Among the high voltage engineering experts, some believe that up to 1 m gap, the air breakdown processes develop as a streamer discharge and therefore in most cases the streamer model and its linearized dependence on the gap size can be used in the analyses. More discussions in this regard are presented in [13], where the author provides:

- synthetized experimental results on dielectric strength of short gaps, used in various empirical and theoretical models,
- somewhat better understanding of the breakdown mechanism of short air gaps, affected by temporal (type of voltage waveform) and spatial (gap arrangement) variations of the electric field,
- examination on the validity of the governing standard for AAC correction procedure for breakdown (BD) voltage for short air gaps.

The Figures 1,a&b [13] show the average breakdown field as a function of gap length with the stress voltage type as parameter.

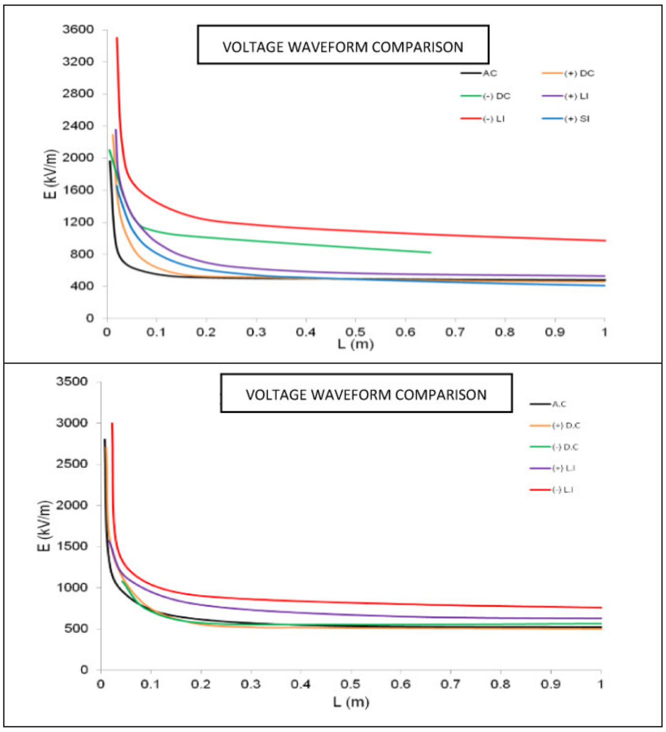

Figure 1, a & b - Comparative graph of average BD field intensity (voltage type parameter) [13]
a) rod – plane (b) rod – rod

These graphs demonstrate the average field intensity decays (almost exponentially with increasing gap length) which remains nearly constant for any increase in length of the gap over 30 cm.

To demonstrate gap arrangement influence, the author uses an extended gap factor concept.

$$k_{gap} = \frac{U_{50}^{any\ gap}}{U_{50}^{Rod-Plane}} \qquad (4)$$

The gap factor concept, as commonly defined (IEC 600 71-1-2) for estimating the U_{50} of any gap configuration based on knowledge of the U_{50} of the rod-plane gap, was established [14] from SI tests of positive polarity, showing that the distance is independent of the shape of the electrodes. In the case of Rod-Plane gaps; the breakdown occurs mainly through a single polarity discharges, depending on the polarity of the rod. The situation is somewhat different in the case of Rod-Rod gaps, where the breakdown occurs by getting involved both: positive and negative discharges (due to the electric field distribution in the gap).

As the negative streamer gradient is approximately 2 up to 4 times higher than the positive streamer gradient (~500 kV/m) the longer the part of the gap bridged by negative streamer the higher the U_{50} thus also the average breakdown field at breakdown. It is also noteworthy that there is an impact made by the gap size and gap arrangement. The graph in Fig. 2 shows the gap factor, as a function of the gap length, while being subjected to AC, DC and LI voltages, and from there it can be concluded that for the gaps above 20 cm, the gap factor rate remains almost constant. However, its value substantially differs across a whole range of the electrode gap, depending on the voltage wave shape (e,g. for AC as well as for both polarities of DC and LI).

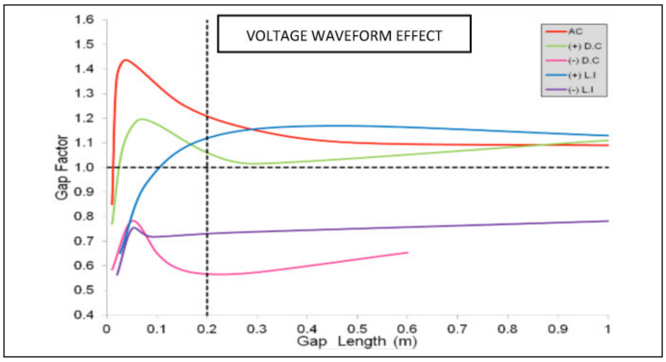

Figure 2 - Gap factor as a function of the gap length (voltage type parameter) [13]

So the search for the gap sizing definition also results in the following information and data:

- Generally, air gaps shorter than 1 m can be categorized as short, due to the absence of a free leader of appreciable length,
- as seen in Figures 1, a & b , still for rather short air gaps the breakdown mechanism is not uniform (average breakdown field varies significantly with gap length), being affected by pre-discharge phenomena, especially with decreasing gap length,
- in summary, it is very difficult to define a size of short or long gaps; and distinctively draw the line of domination between streamer and leader, and their influences. This quite pragmatic criterion can be denoted as a gray or overlapping zone.

The above leads to a conclusion that a criterion for short gaps, of being 1 m and less, can be commonly adopted.

So, the short gaps of (< 1 m) need to be considered separately from long gaps because of the dominant influence of the grounded electrode on the early development of the ionization phenomena in the stressed electrode and therefore different breakdown physics (streamer dominancy) compared to long gaps. The assumptions for short gaps, used in IEC standards (it assigns the exponent *m* to be unity (*m*=1)) and absence of humidity parameter for short gaps, have often been argued in the literature as invalid.

For short gaps the available methods show discrepancies especially related to humidity corrections which have not been incorporated in the standards. The IEC standard [2] doesn’t specifically mention short gaps, but it is apparent that the g-parameter criterion is not applicable for short gaps because the average positive streamer propagation gradient is greater than 500 kV/m.

The definition of the boundary between long and short air gaps is still a subject of discussion. However, a way of setting the limit was shown in [16] considering the influence of the grounded electrode on the streamer development.

In short gaps with rod-plane electrodes, the proximity of the earthed plane affects the first corona and the development of the streamers, increasing the necessary electric field for sustaining secondary streamers propagation and a later electric breakdown. This effect raises the average gradient E_{50} necessary for breakdown producing values greater than 500 kV/m in short gaps. This “short gap effect” is put in evidence adding negative ions in the gap, which reduce the inception voltage and the injected charge at the first corona. Consequently the breakdown voltage decreases about 10% for air gap of 15 cm, 6 % on 30 cm and it has no effect for gaps of 60 cm and more, as shown in Figure 3 [15].

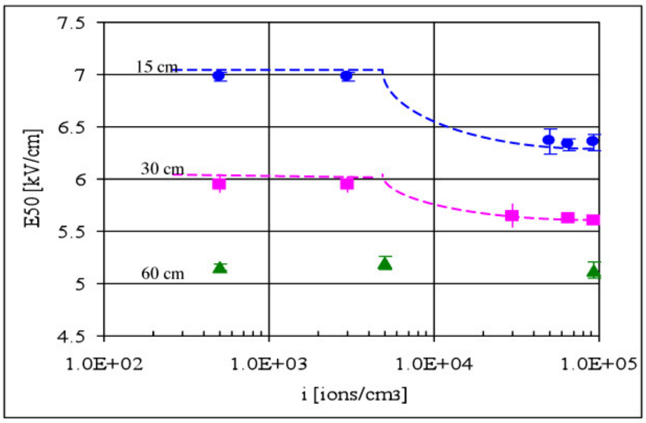

Figure 3 - Breakdown field as a function of negative ion density. [15]

In this last case the measured E_{50} value is close to 500 kV/m. The determination of boundary distances for this electric quenching effect would be a useful tool to characterise short-gap distances, e.g. lower than 60 cm for rod-plane electrodes. This effect could be explained assuming that negative ions facilitate the first corona inception at lower voltages, then the electric charge of this corona is smaller compared with the charge produced by higher inception voltages and the grounded electrode influence become negligible on the streamer development.

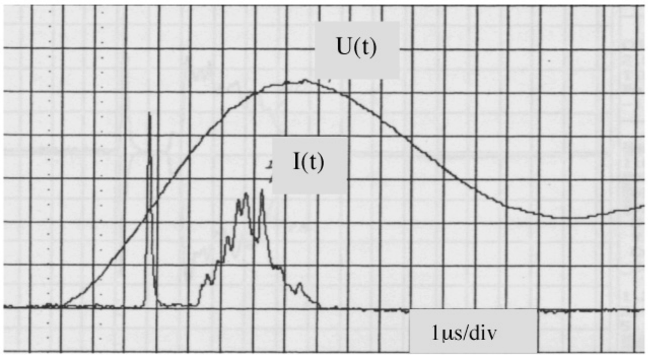

Figure 4. - Voltage (50 kV/div) and current (0.25 A/div) under natural atmospheric conditions (negative ion density 500 cm^{-3}).[14]

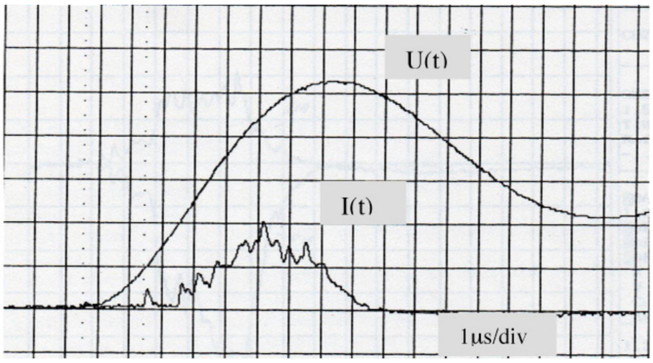

Figure 5. - Voltage and current under artificial negative ion density 20000 cm^{-3}.[14]

Figures 4 and 5 show the voltage and current for natural atmospheric conditions (with natural negative ion density of about 500 cm^{-3}) and for artificial negative ion density (20000 cm^{-3}), respectively for a rod-plane gap of 60 cm. It is evident that artificial ions induce a first corona inception at low voltage, with current of almost 10%, “making as” if the distance between the electrodes increases.

As shown in [15], Figures 6 and 7 highlight the effect of ions acting as a “converter” of short gap into long gap. The reduction of the charge produced in the first corona in presence of artificial ions is confirmed by the record of photo-ionization light with a photomultiplier with sensitivity between 300 and 600 nm.

The significant effect of the pre-discharge mode on the breakdown voltage for gaps less than 100 cm has been noted by Feser [16] with alternating and direct voltages, as well as with switching and lightning impulses applied to rod-plane and rod-rod gaps in air. For impulse voltages stress he detected mixed breakdown distributions at a small range of gap distances. It has been shown that it is almost impossible to define absolute limits of transition ranges as these depend on several parameters. The parameters that influence the transition range are the geometry and arrangement of the gap, the atmospheric conditions and the voltage polarity, but in most of the reported cases for different voltage stress the transition distance falls between 40 and 100 cm.

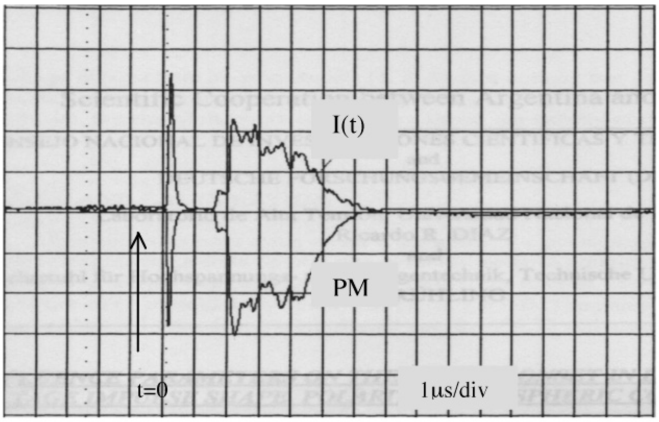

Figure 6 - Current and light under natural ion density.[15]

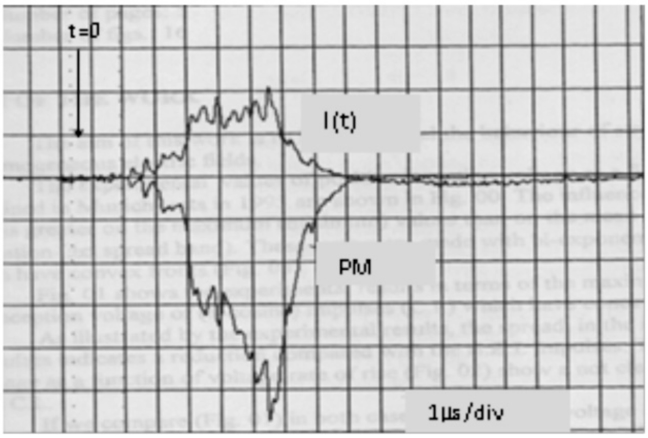

Figure 7 - Voltage and current under artificial negative ion density.[15]

3.2 Short gap Altitude and Atmospheric Correction (AAC) basics and current practice(s) - summary

As it has been concluded in literature, the influence of air density is most significant on the streamer formation and the way on how it propagates.

So the short gaps of < 1 m are being considered as a separate group of corrections because of their more homogeneous fields and therefore different breakdown (streamer dominancy) physics compared to long gaps. This leads to special considerations regarding short gaps and the available research has been summarized to give an overview of the current knowledge of atmospheric/altitude correction factors.

The assumptions used in IEC standards for short gaps (it assigns the exponent *m* to be unity (*m*=1) and that there is no humidity parameter for short gaps) are proven invalid. For short gaps the available data show discrepancies to the correction method especially related to humidity corrections which are not defined for short gaps in the standards.

3.3 Testing and Experiments with DC Voltage

Open air laboratory tests were conducted at altitudes ranging from 1 m to 1 880 m using positive polarity DC voltage source (see test data in Appendix). The air gap length during the tests was adjusted in steps of 0.05 m from 0.10 m to 0.50 m. For every gap length, 5 breakdowns were conducted by slowly increasing the voltage until breakdown. Between each breakdown, a 5-minute time lapse was observed to allow any accumulated space charge to dissipate. The electrodes comprised of a rod of 16 mm copper tube with a square end cap (with bevelled edge). The ground electrode was a 1 m square metallic plate.

It was intended to map the breakdown voltage obtained at standard atmospheric conditions to what would be expected at any other higher altitude location using the converse IEC60060-1 method. The IEC60060-1 standard atmospheric conditions are: temperature - 20° C, air pressure - 101.3 kPa and absolute humidity - 11 g/m3. The conditions at the sea level test site (Clansthal near Durban, South Africa) although very close to standard conditions, were slightly offset. The temperature was 23° C, absolute humidity at 19 g/m3, and pressure at 101.2 kPa. The altitude at this site is less than 1 m above sea level as can be visually deduced in the image of Figure 8.

In order to simulate altitudes higher than 1880 m.a.s.l, a variable pressure vessel was used for the breakdown tests. The procedure was similar to the open air tests except that the biggest gap length could only be 0.3 m. The pressurised vessel test setup is detailed in [17]. Gap breakdown tests were conducted in the vessel at various pressures up to the lowest pressure of 300 mbar that simulated an altitude of 5200 m.a.s.l. Due to the constrained space in the chamber, a 10-minute waiting period was observed between breakdowns to allow adequate dispersion of accumulated space charge. Environmental conditions were recorded for each gap length and each pressure level tested. It was noted that under steady state in the vessel, the reduced pressure did not translate to reduced temperature.

Figure 8 - A picture of the test setup at sea level in Clansthal near Durban South Africa

RESULTS - Open air tests: Except for humidity of 19 g/m^3, instead of 11 g/m^3, the altitude and temperature at Clansthal (sea level) were practically standard conditions. The obtained gap breakdown voltages were however still corrected to standard conditions using the IEC60060-1 [2] method. The corrected results however were not different from uncorrected values as shown in Figure 9.

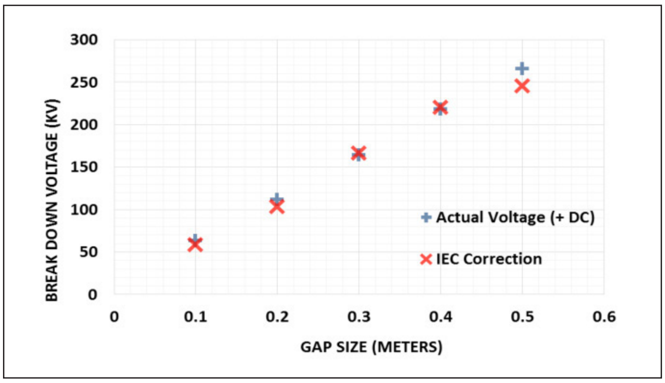

Figure 9 - Sea level breakdown voltage corrected to standard atmospheric conditions using IEC60060-1(2010).

The obtained sea level results were then used in the converse IEC60060-1 [2] method (inclusive of humidity correction) to predict the breakdown voltages and compared with actual tests results for the gaps investigated at various higher altitudes. A method devised by Calva [3] was also used to predict the breakdown voltages. At low altitude (130 m.a.s.l.), the actual breakdown voltages, those obtained through the IEC60060-1 converse method and those through the Calva method are comparatively shown in Figure 10.

The same procedure was repeated for the higher altitude tests where the test site was 1 880 (m.a.s.l.). At low altitude both the IEC and Calva prediction results are within the 5% accuracy limits relative to the actual test results. It can therefore be concluded that at low altitudes, for short gaps, both the IEC and Calva methods are equally reasonably accurate.

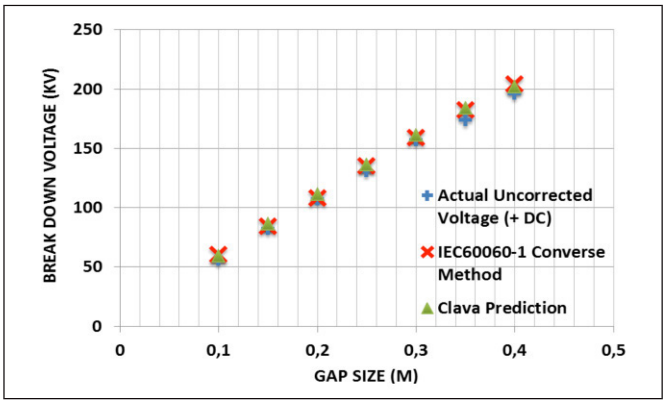

Figure 10 - Plot of low altitude (130 m.a.s.l.) actual breakdown voltage for various gaps compared with predictions calculated using convoluted IEC60060-1(2010) as well as the Calva methods.

At the higher altitude of (1880 m.a.s.l, being close to the applicable altitude limits of the IEC60060-1 method) there are notable, trends as the gap increases beyond 0.25 m, as shown in Figure 11. While the Calva prediction remains relatively closer to the actual test results, both the IEC60060-1 and Calva predicted values become larger than the actual test results. The deviations increase with increase in gap size where for a 0.3 m gap, the Calva and IEC values are respectively 23% and 45% higher than the actual. At 0.5 m gap size, the differences become 26% and 56% respectively.

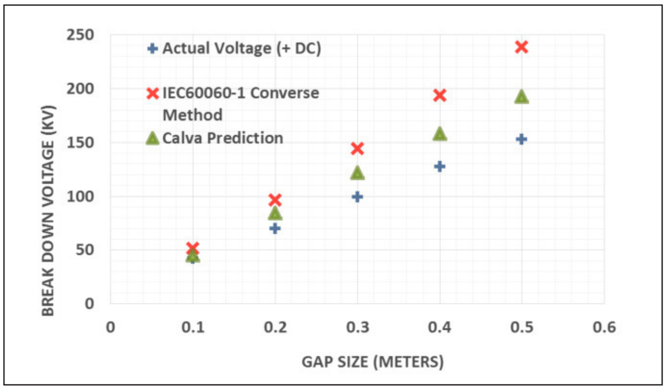

Figure 11- Plot of high altitude (1880 m.a.s.l.) actual breakdown voltage for various gaps compared with predictions calculated using converse IEC 60060-1(2010) as well as the Calva methods.

RESULTS - Pressure vessel tests: The IEC60060-1 converse method could not be used to map the sea level breakdown values to altitudes simulated in the variable pressure chamber as the altitudes are beyond the boundaries within which the standard is applicable. Therefore only the Calva method was used to predict the gap breakdown voltages in comparison to the actual breakdown voltages as shown in Figure 12.

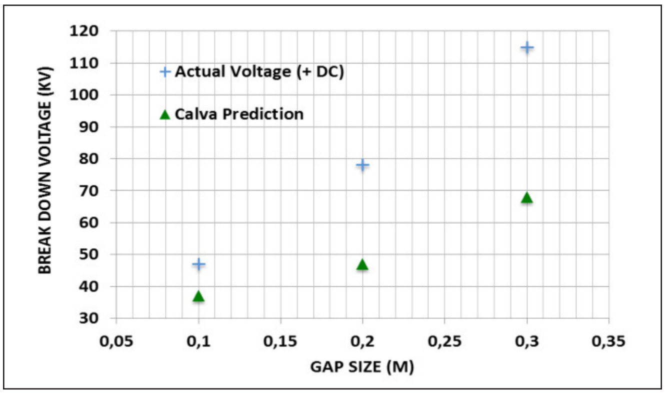

Figure 12- Plot of pressure vessel simulated very high altitude (5200 m.a.s.l.) actual breakdown voltage for various gaps compared with predictions calculated using convoluted IEC 60060-1(2010) as well as the Calva methods.

The latter are significantly lower by an average difference of 33% for the investigated gap range of 0.1 m to 0.3 m. The differences in the trends however suggest a possibility of modifying the Calva model to be more accurate at altitudes above 1880 m.a.s.l.

4. Conclusions

The findings presented in the present paper can be summarised as follows:

- The current atmospheric and altitude correction methods arrive at different results, though they are based on the same test data.
- The g-factor method in IEC 60060-1 [2] is a too large simplification of the complex discharge process and can result in appreciative errors if the gap length is not defined by the applied voltage.
- One correction method would be desirable, but considering the different needs in the main applications seems not feasible.
- The correction assumptions for short gaps, exponent m being unity and no humidity corrections, has been proven invalid by the available test data and need to be reconsidered.
- For positive polarity DC voltage, at lower altitude and for short gaps, both the IEC60060-1 and Calva methods are reasonably accurate.
- The proposed method by Calva has given better estimation for reported test results under DC voltage than that by IEC 60060-1, but needs modification to be accurately applicable.

5. Acknowledgments

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Appendix: Test Data of open air Experiments with DC Voltage

Table A1: Measured test data at different altitudes with corrections

Altitude (m.a.s.l.)	Gap (m)	Actual Voltage (+ kV DC)	Air Pressure (hPa)	RH (%)	Temp (°C)	Kt	IEC 60060-1 Correction (kV)	Calva Prediction (kV)	IEC60060-1 Converse Method (kV)
1	0.1	63.6	1012.4	89	23.6	1.09	58.6	69.1	69.0
	0.2	112	1012.5	90	23.4	1.09	103.1	129.0	121.7
	0.3	164	1012.8	92	24	0.99	166.3	187.9	161.8
	0.4	218	1012.7	92	23.3	0.99	220.5	241.8	215.5
	0.5	266	1013	91	23.2	1.08	245.6	294.6	288.1
130	0.1	56.92	987.8	48.6	27.6	0.98	57.9	60.9	62.6
	0.2	107.62	986.1	51.8	27.8	0.99	108.2	114.9	111.4
	0.3	157.1	985.2	54.9	27.2	1.00	157.2	166.5	163.9
	0.4	196.76	985.5	46	25.5	0.96	204.9	207.2	209.3
1880	0.1	42.116	815.16	52.87	20.5	0.81	51.9	45.2	51.6
	0.2	69.949	815	52.71	20.62	0.86	81.2	84.4	96.5
	0.3	99.307	815	53.65	20.29	0.88	113.2	121.7	143.9
	0.4	127.19	815	54.27	20.05	0.89	143.2	157.7	193.6
	0.5	152.595	815	53.69	20.21	0.90	170.1	192.6	238.7