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Breakdown Current Measurement For Detecting The Initiation Of Two-Stage External Flashovers Of A Vacuuminterrupter

Tobias Jesberger | ITG Vacuum Workshop | 30.08.2024

Agenda

- 1 Motivation
- 2 Test setup
- 3 Measurement results
- 4 Generating expected signal
- 5 Comparing results
- 6 Conclusion

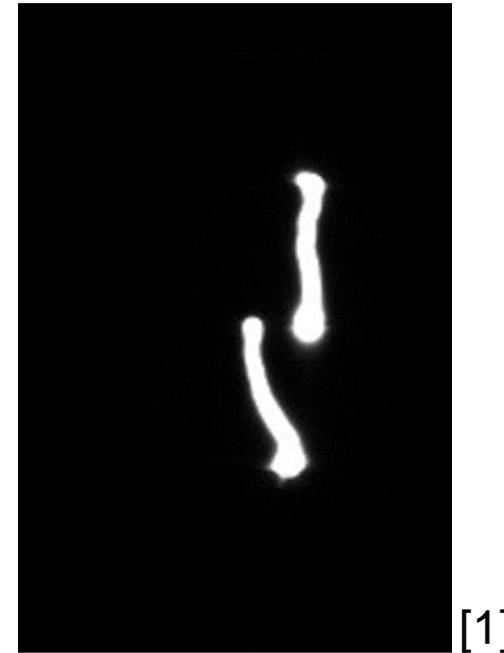
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Motivation

After observing two-stage breakdown paths current measurement setup is to be established to gain a better understanding of the breakdown mechanism

- Dielectric investigations on the VG6 vacuum interrupter from ABB
- Experiments in a two-stage lightning impulse circuit
- Two-stage breakdown path identifiable

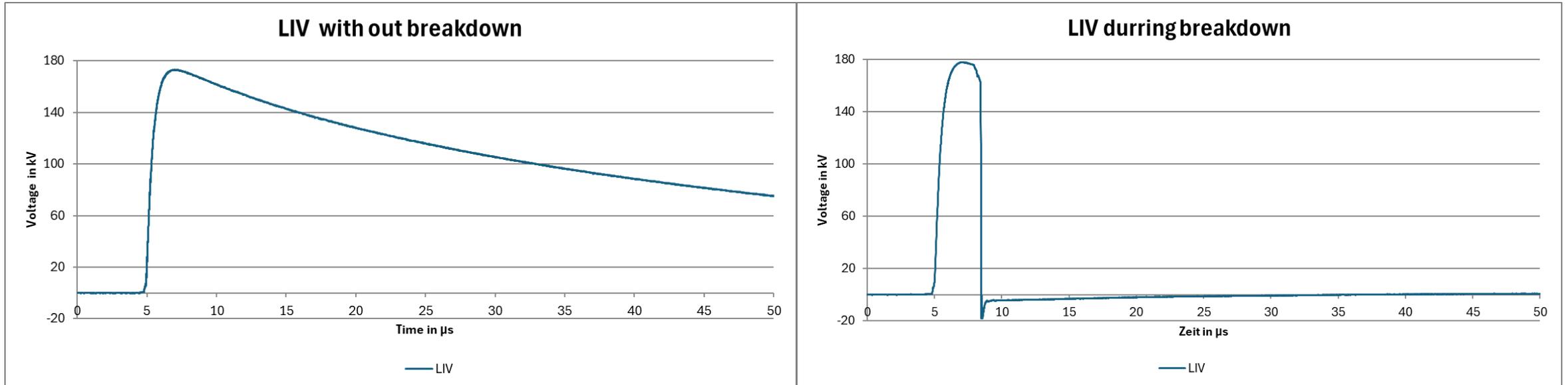


[1]



Motivation

The current setup allows only the evaluation of the LIV



→ Breakdown current measurement is supposed to provide insights into the initiation of the breakdown and its mechanism

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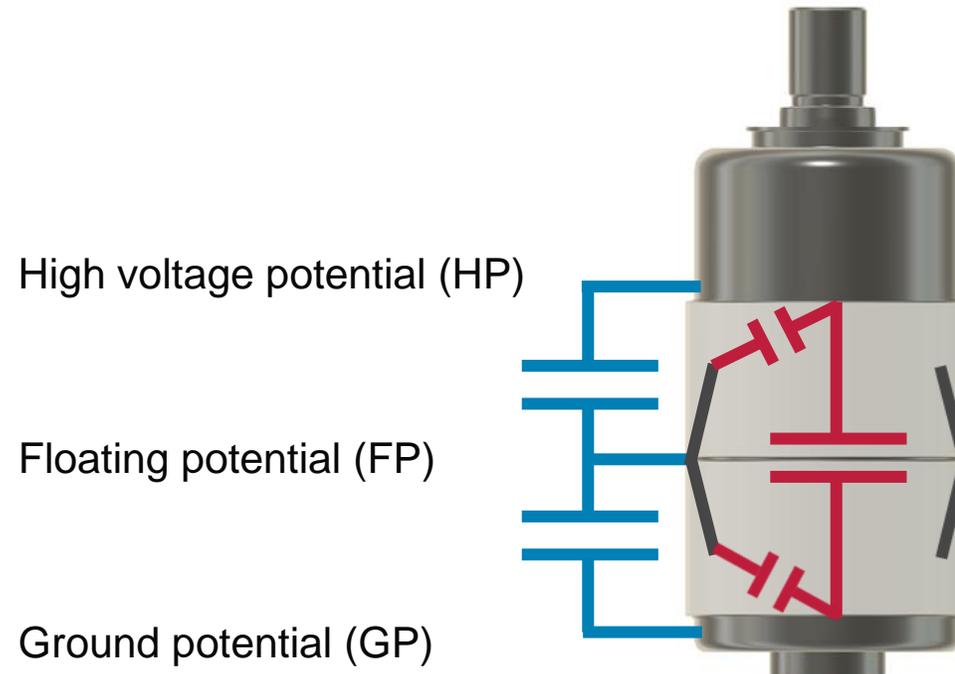
6 Conclusion

Test setup

A vacuum interrupter is the device under test and its structure in the test field.

- Vacuum interrupter ABB VG6
- Rated lightning impulse voltage 95 kV
- Contact gap 17 mm

- Tested in air without outer insulation
- Isopropanol cleaning
- Elevated position for less ground potential influence



Test setup

For the measurement of the breakdown current 1 Ω resistors are required

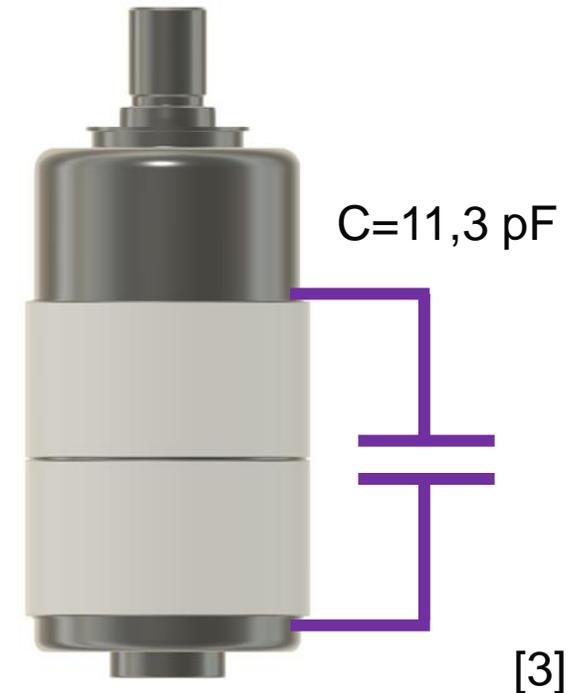
- To determine the correct measuring resistor for the measurement, the current during the breakdown is estimated

$$i = C \cdot \frac{dU}{dt} \quad [2]$$

$$\frac{\Delta U}{\Delta t} = \frac{150 \text{ kV}}{0,5 \mu\text{s}}$$

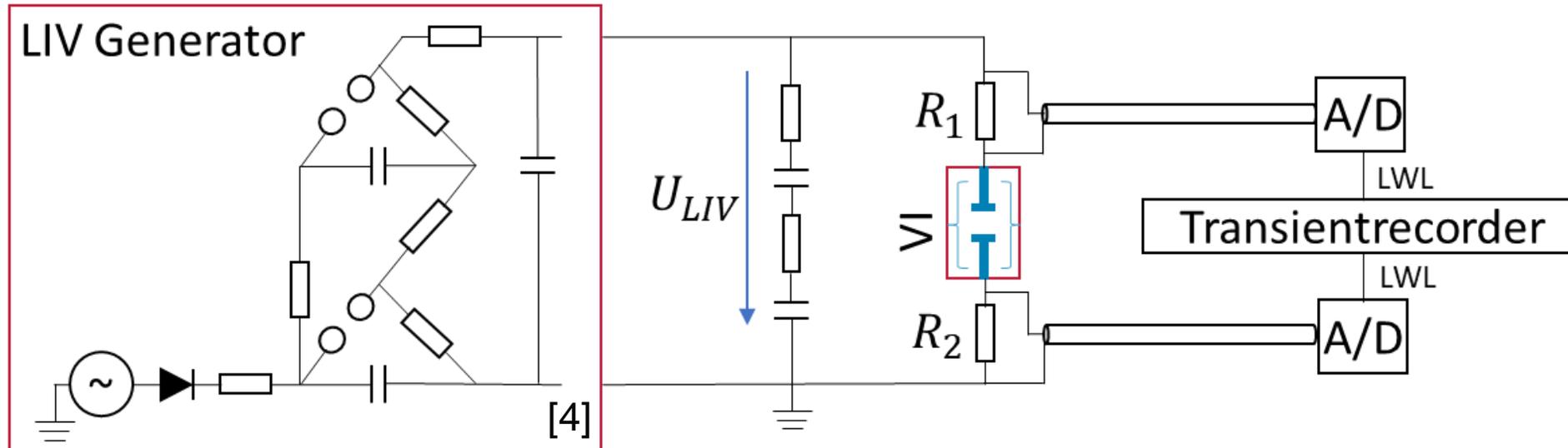
$$i = 3,4 \text{ A}$$

- The current can be measured using a 1 Ω resistor



Test setup

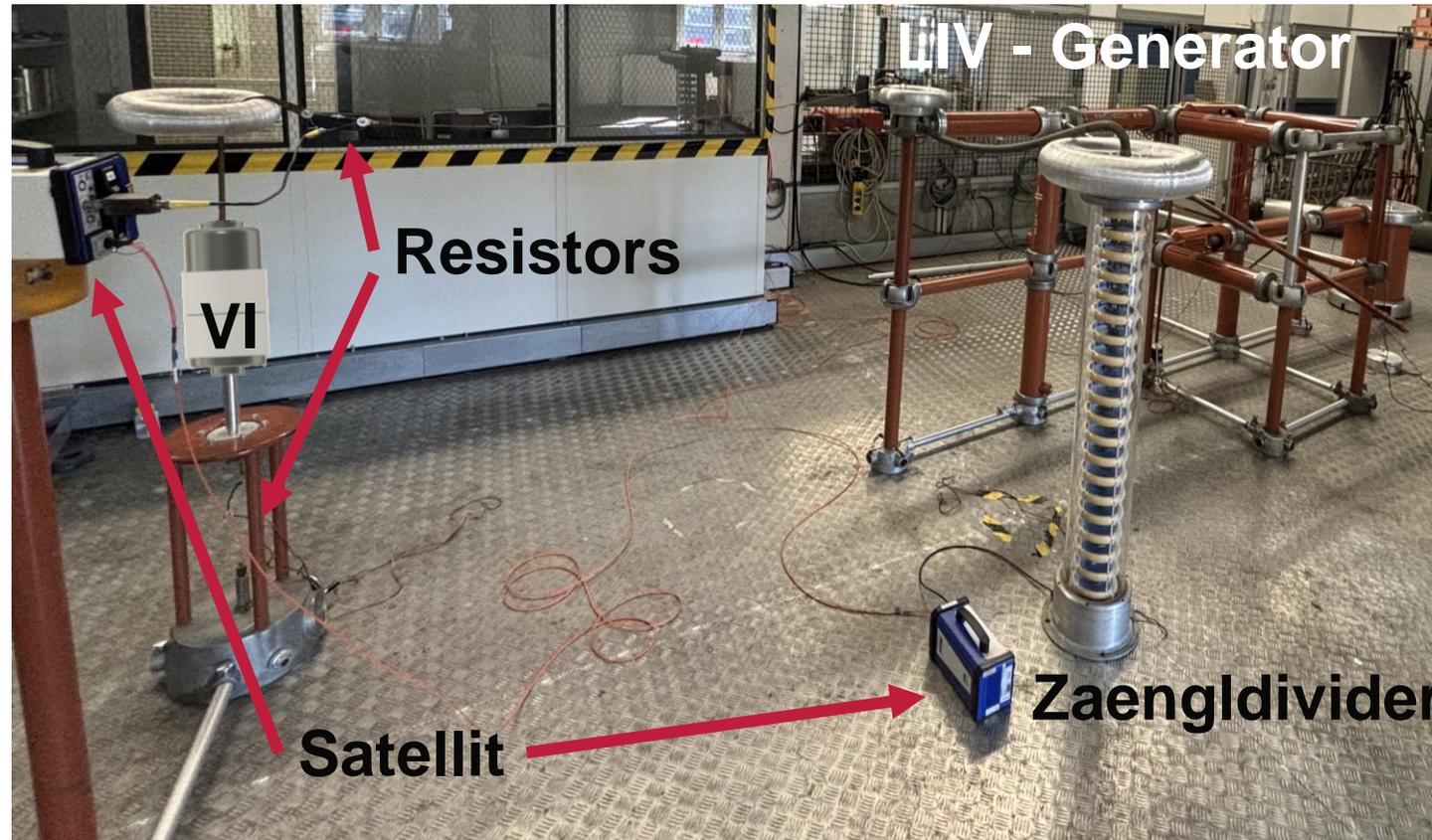
The LIV is provided by a 2-stage Marx-Generator and the current is measured via two 1Ω resistors



- The Generator with a fronttime of $1,25\ \mu\text{s}$ and a time of half value of $45,6\ \mu\text{s}$ produces a standardized impulse voltage [5]
- Zaengldivider with a divider ratio of 2274
- Current measurement with $R_1 = R_2 = 1\ \Omega$
- Coaxial cable with a characteristic impedance of $50\ \Omega$
- HV6600 as A/D converter with a samplerate of $100\ \text{MS/s}$
- Transientrecorder Genesis 7t from HBM

Test setup

Test setup placed in the high voltage laboratory of elenia consisting of voltage divider, DUT and LIV generator.



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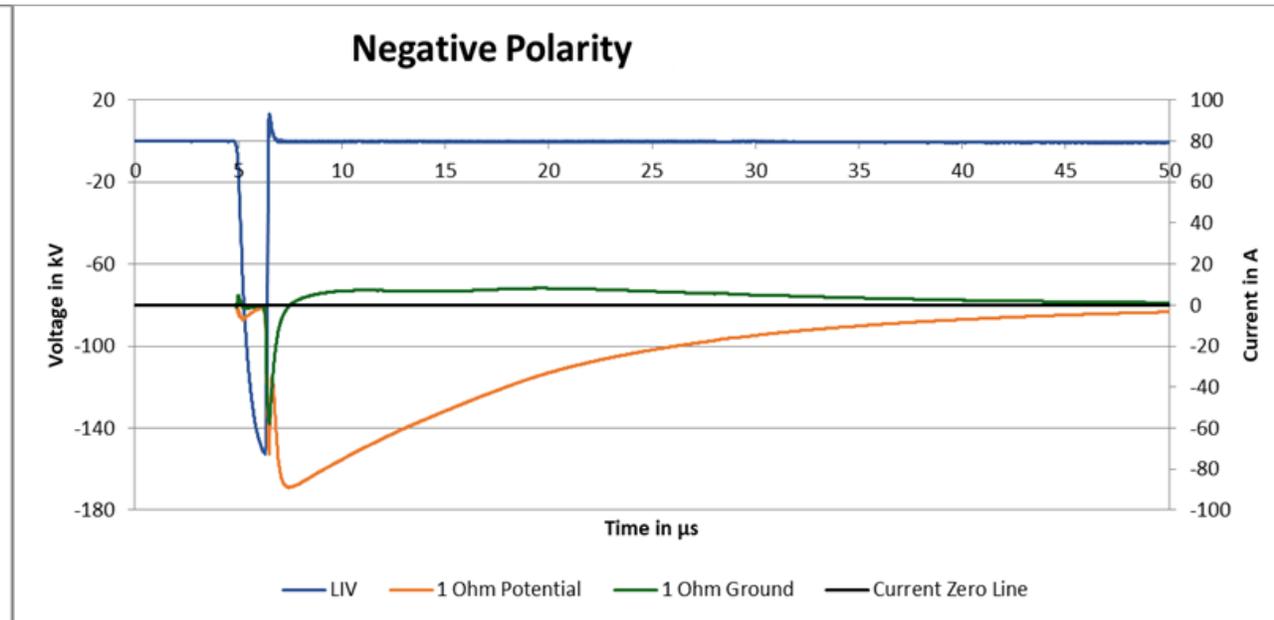
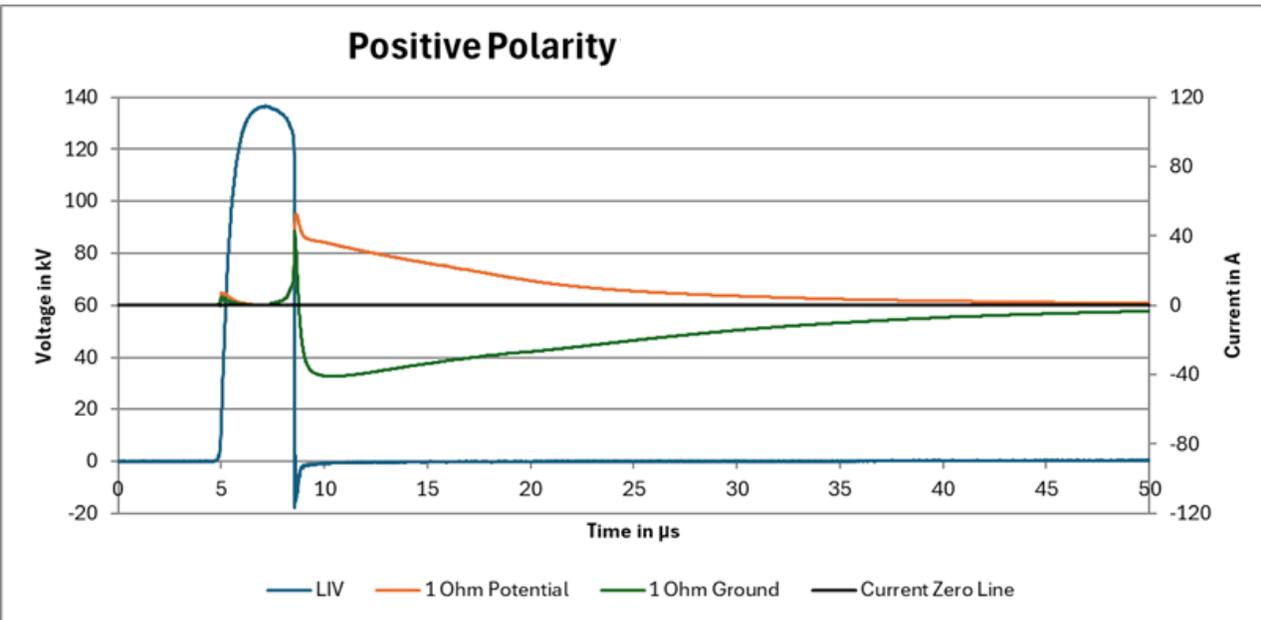
4 Generating expected signal

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Measurement results

The current during the breakdown was measured for positive and negative polarity



- Butterworth filter with a cut off frequency of 500 kHz
- Negative discharge curve at ground potential with a positive peak current during the Breakdown
- Positive discharge curve at high voltage potential

- Butterworth filter with a cut off frequency of 500 kHz
- Negative discharge curve at highvoltage potential
- Negative discharge curve with a positive offset at ground potential

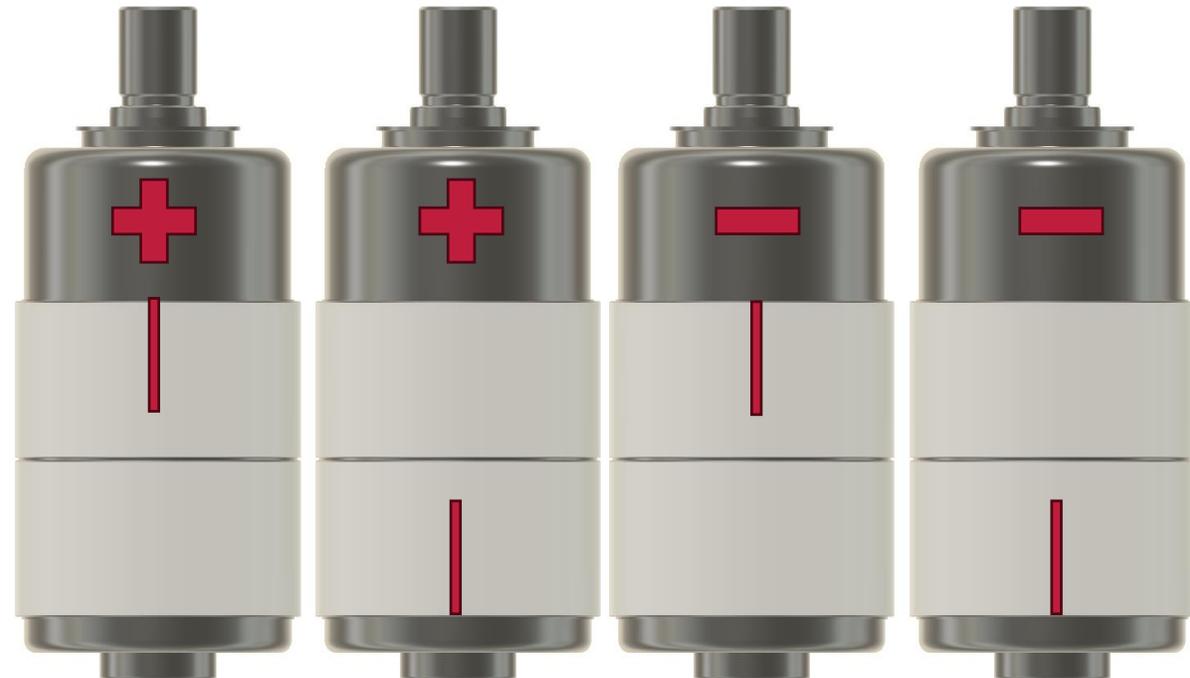
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Generating expected signal

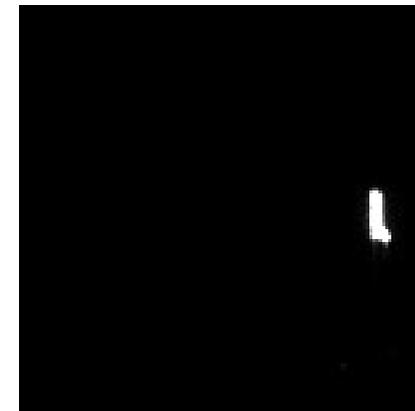
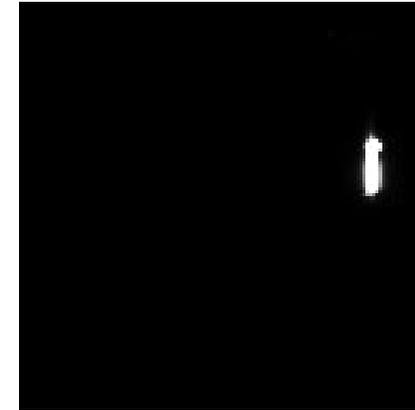
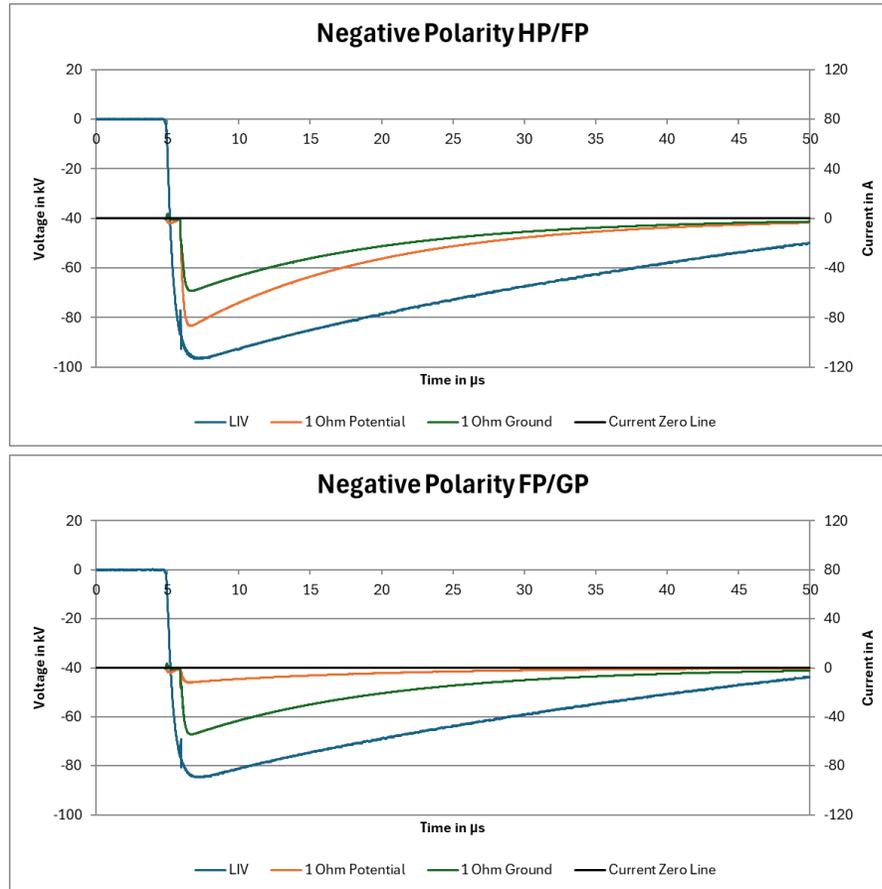
To simulate the breakdown behavior depending on the starting point, a stranded wire is used to bypass a part of the insulation of the vacuum interrupter.

- Stranded wire to bypass the insulation partly
- Gap between wire and metall vapor condensationshield is 2 cm
- Testing with negativ and positiv LIV



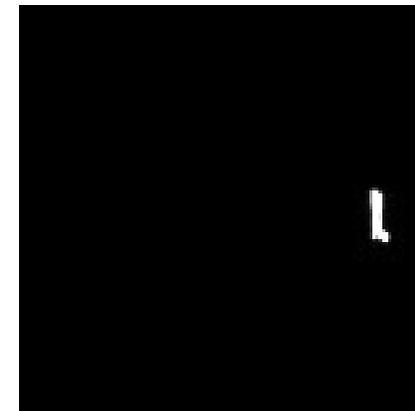
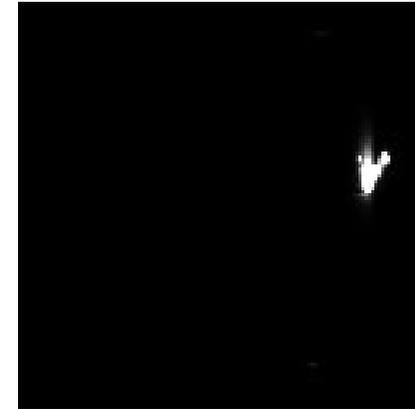
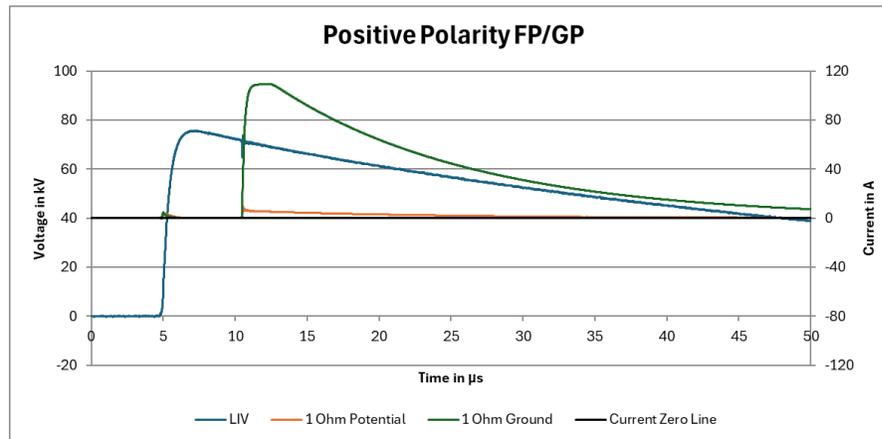
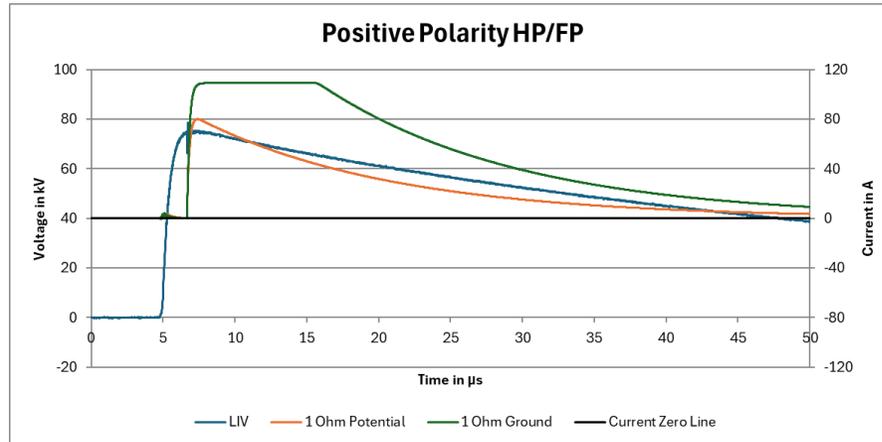
Generating expected signal

To simulate the breakdown behavior depending on the starting point, a stranded wire is used to bypass a part of the insulation of the vacuum interrupter.



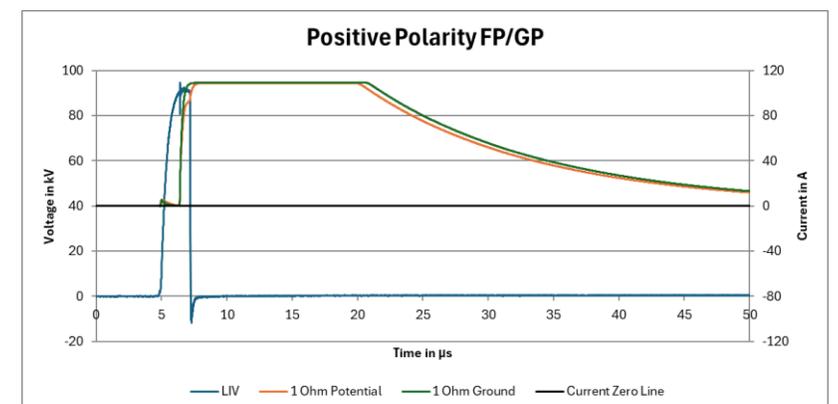
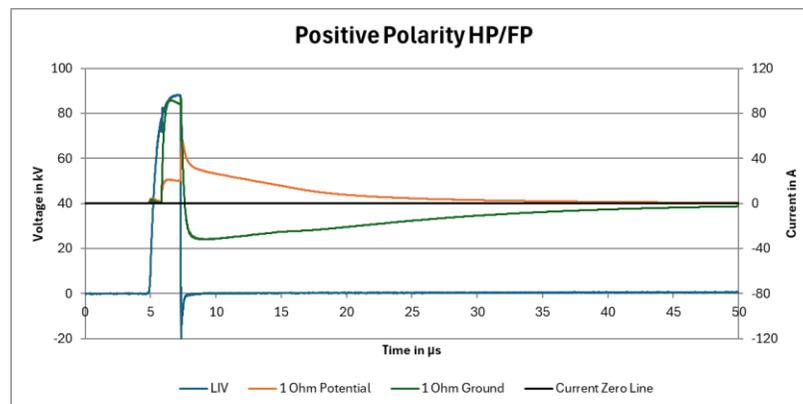
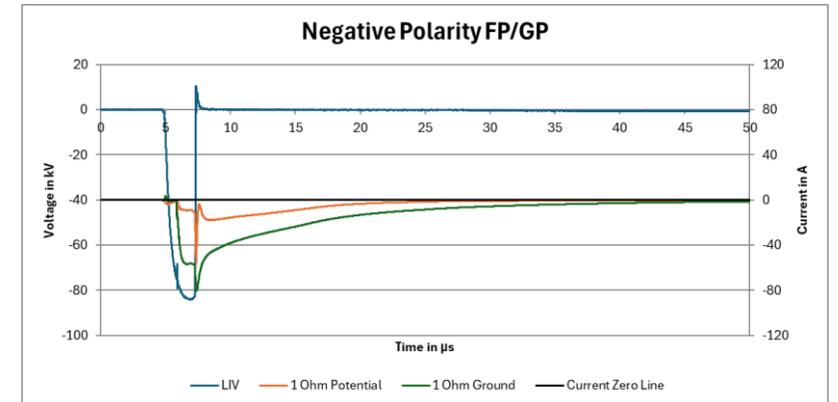
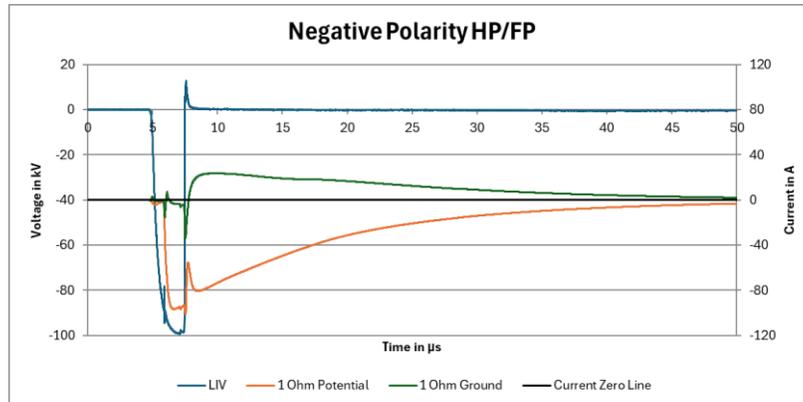
Generating expected signal

To simulate the breakdown behavior depending on the starting point, a stranded wire is used to bypass a part of the insulation of the vacuum interrupter.



Generating expected signal

For the four arrangements with stranded wire, a breakdown was deliberately induced in order to later compare the behavior during the breakdown.

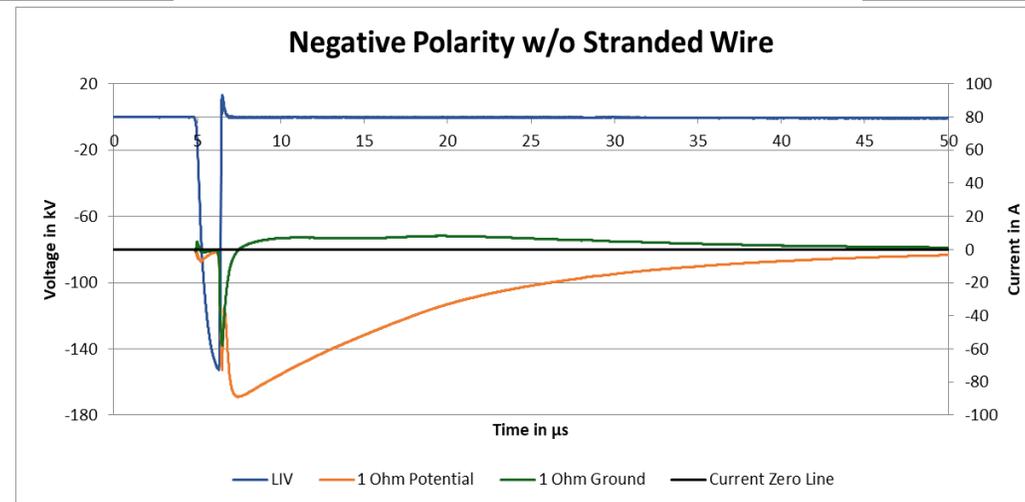
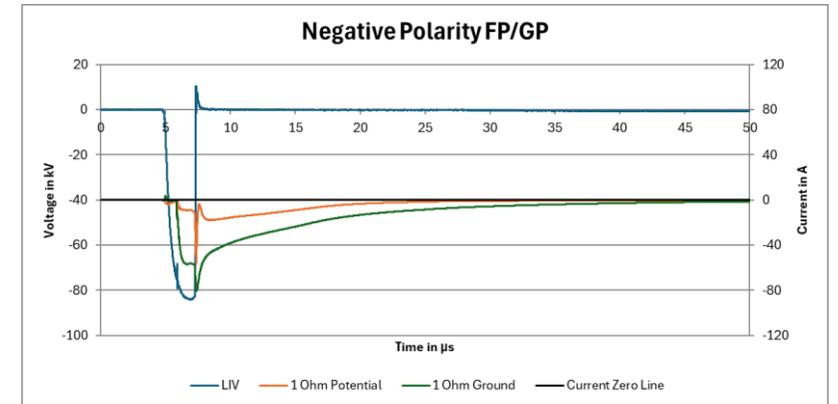
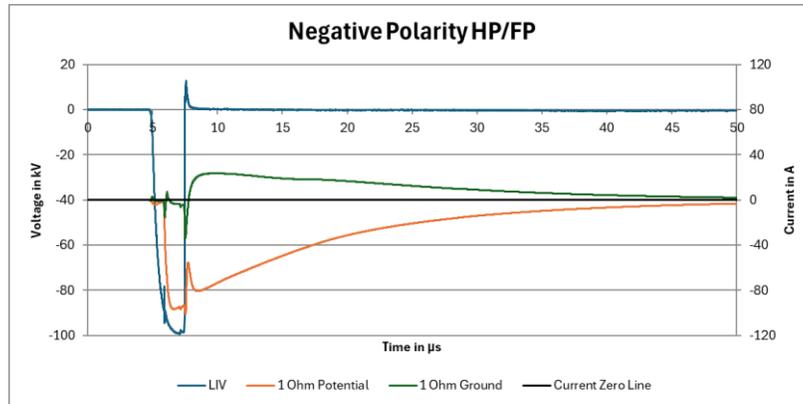


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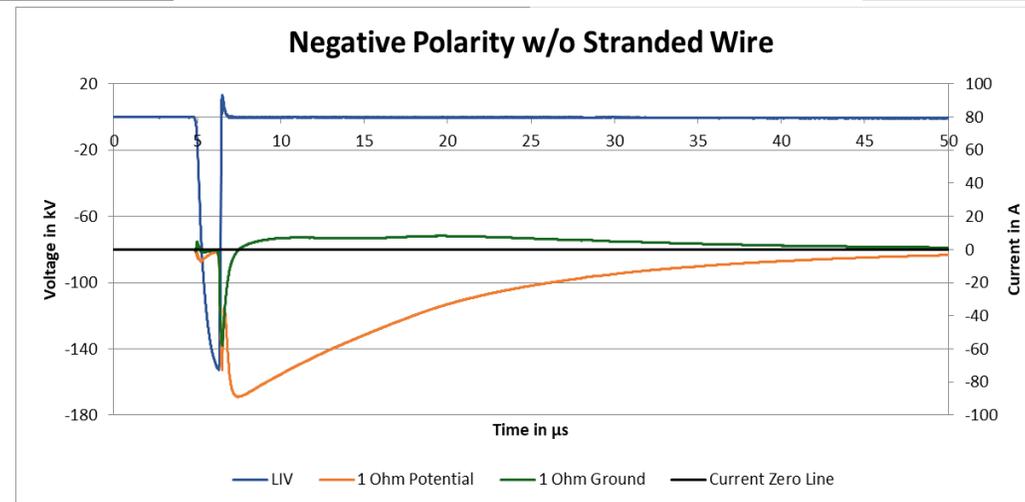
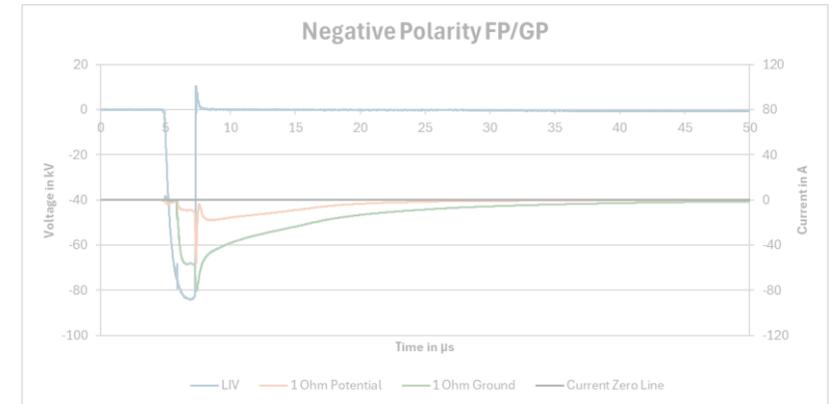
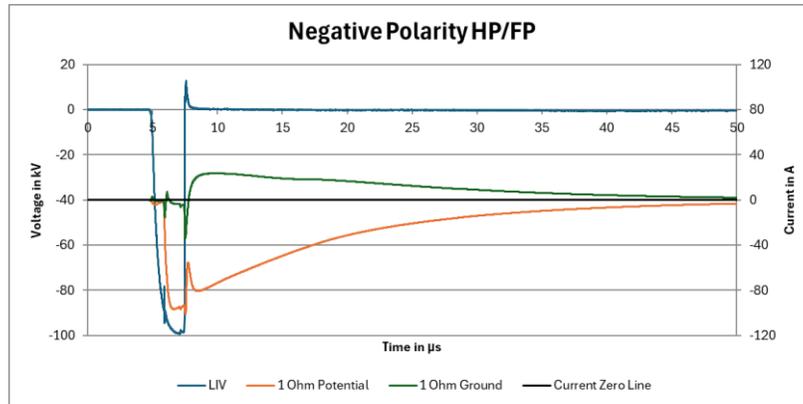
Comparing results

The initial breakdown with negative polarity occurs between high potential and the metal vapor shield



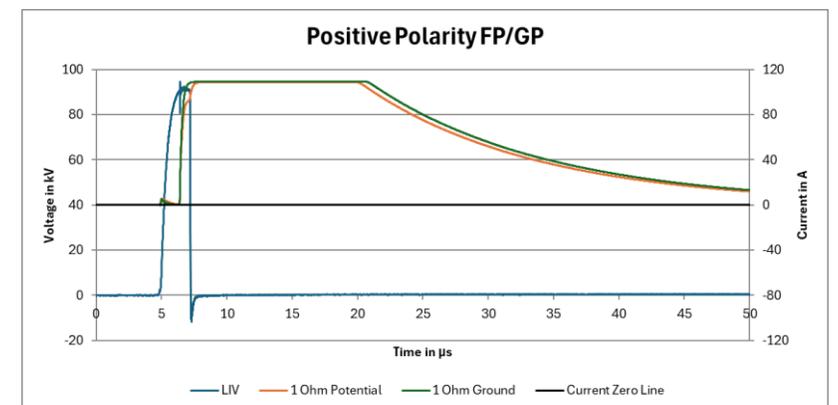
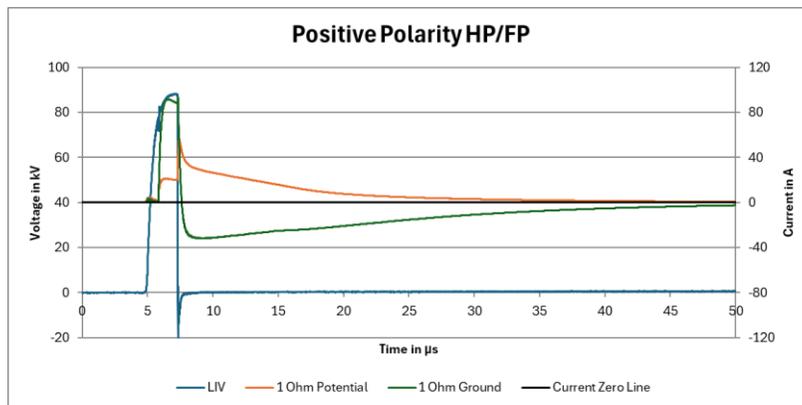
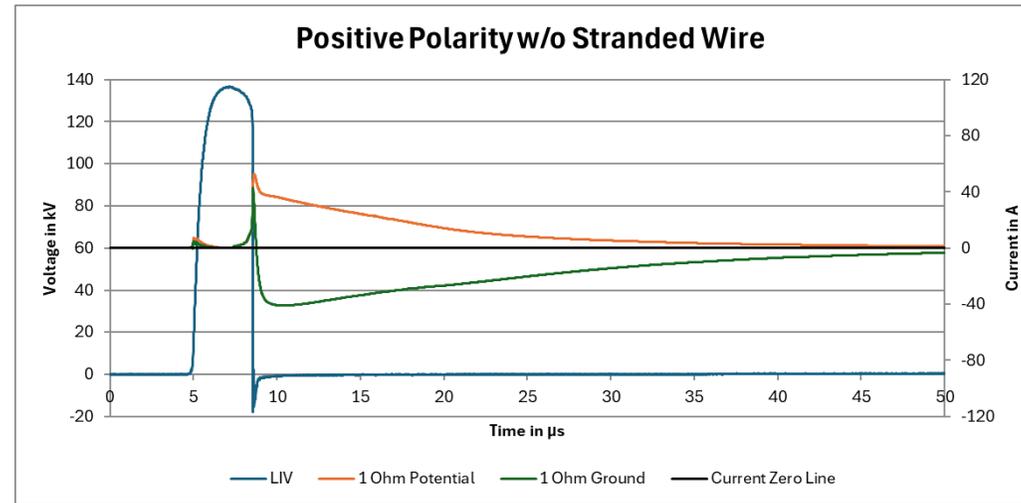
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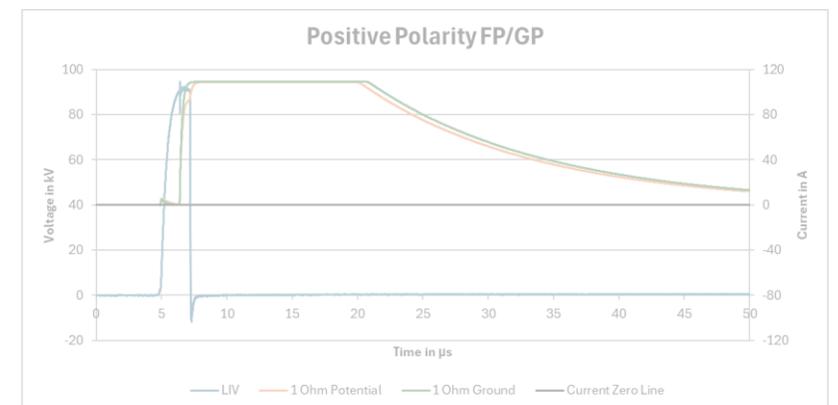
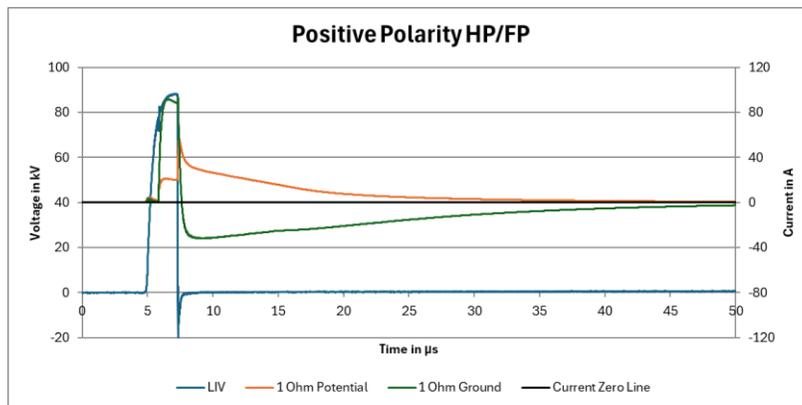
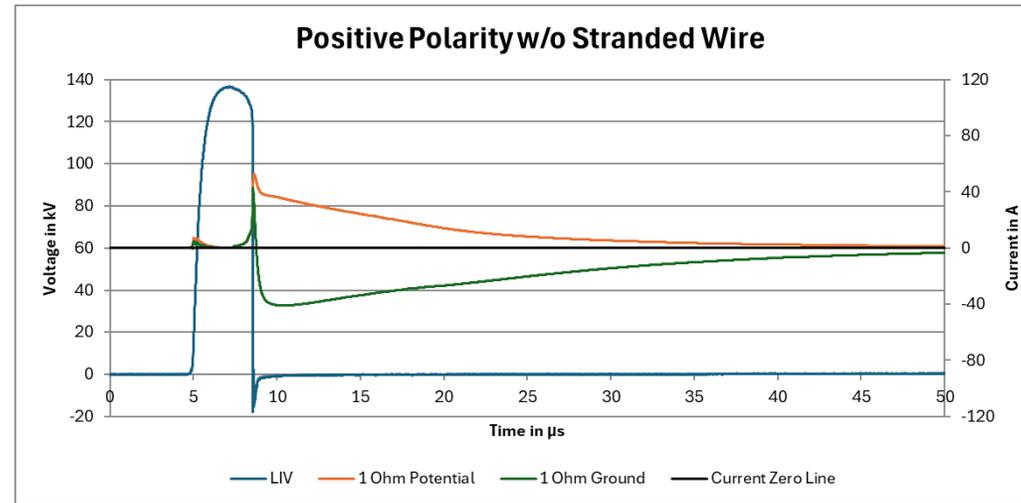
Comparing results

The initial breakdown with positive polarity occurs also between high potential and the metal vapor shield



Comparing results

The initial breakdown with positive polarity occurs also between high potential and the metal vapor shield



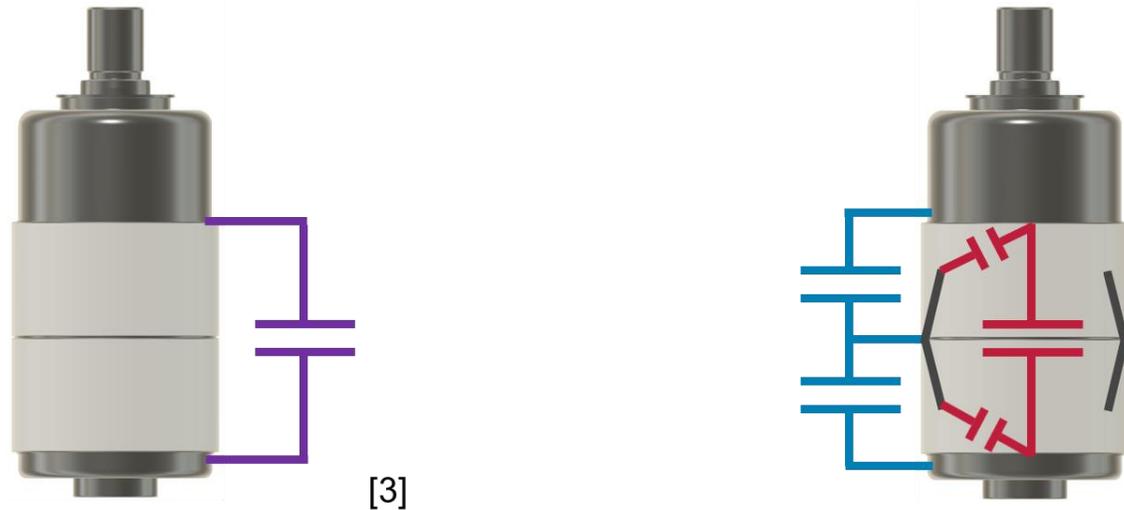
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Conclusion

With a breakdown current measurement, the initiation of two-stage external flashovers of a vacuum interrupter can be identified.

- It is possible to identify the first breakdown path by comparing the current measurements from the provoked first breakdown point with the real breakdowns.
- The initial breakdown occurs between high voltage potential and metal vapor condensation shield no matter what polarity.
- To fully explain the behavior of the current, all values of the capacitance network must be known. This is currently not the case.





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Thank you for your attention

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References:

- [1] Flügel, K.; Jesberger, T.; Gentsch, D.; Kurrat, M. (2024): Effect of External Field Control Ring for Vacuum Interrupter using Lightning Impulse Voltage, 2024 IEEE International Conference on High Voltage Engineering and Application
- [2] Sentker, Peter (1997): Die elektrische Festigkeit von Mehrfachunterbrechungen im Hochvakuum. Dissertation. Technische Universität Braunschweig, Braunschweig.
- [3] Flügel, Karen; Meyer, Timo; Gentsch, Dietmar; Kurrat, Michael (2023): PARTIAL BREAKDOWN DETECTION IN VACUUM Partial breakdown detection in vacuum interrupter und lightning Impulse Voltage. In: *International Symposium on High Voltage Engineering 2023*.
- [4] Schon, Klaus (2021): Hochspannungsmesstechnik. Grundlagen – Messgeräte - Messverfahren. 2. Auflage. Wiesbaden, Heidelberg: Springer Vieweg.
- [5] VDE DIN EN IEC 60060-1, 02.12.2022: Hochspannungs-Prüftechnik