Dielectric Testing of Vacuum Circuit Breakers for High-Voltage Applications above Distribution Voltage Level

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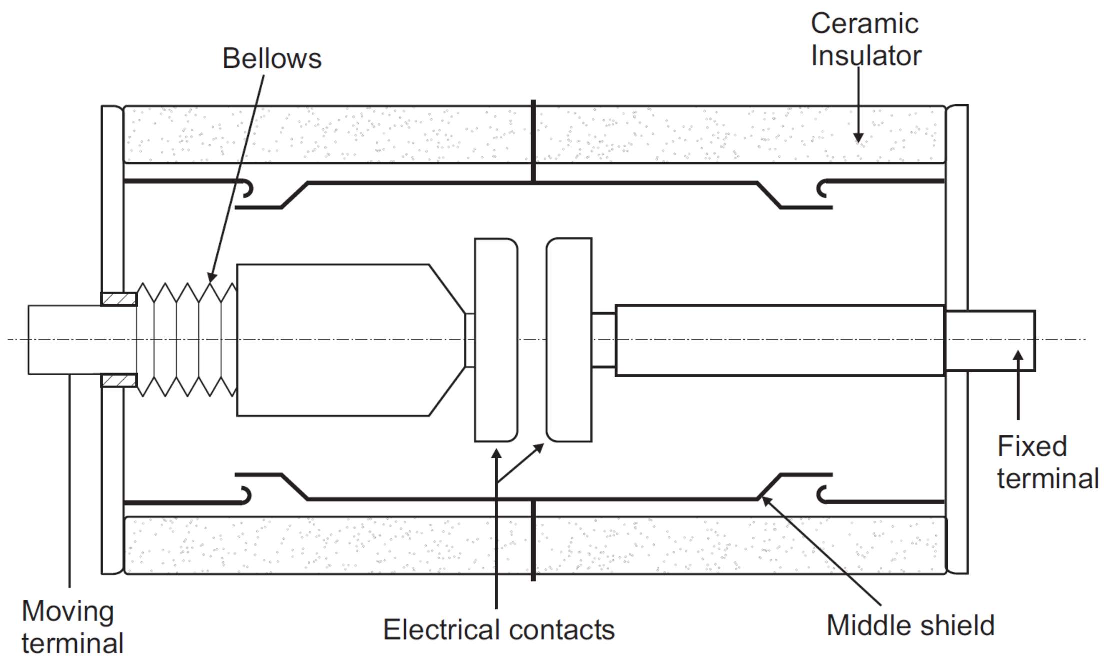
Introduction

Vacuum interrupters (VI) are well established in the distribution voltage level (up to 52 kV) of the electrical power supply system. In order to establish this technology at higher voltages, which may be desirable to reduce the use of sulfur-hexafluoride, the usual insulating and arc quenching medium in high-voltage circuit breakers, the dielectric withstand reliability – especially when switching capacitive loads – must be increased. In this contribution, we present our approach to investigate the field emission currents as well as the micro discharges of commercial VI for test voltages up to 200 kV.

Vacuum Interrupters



Cross-section of a vacuum interrupter [1]

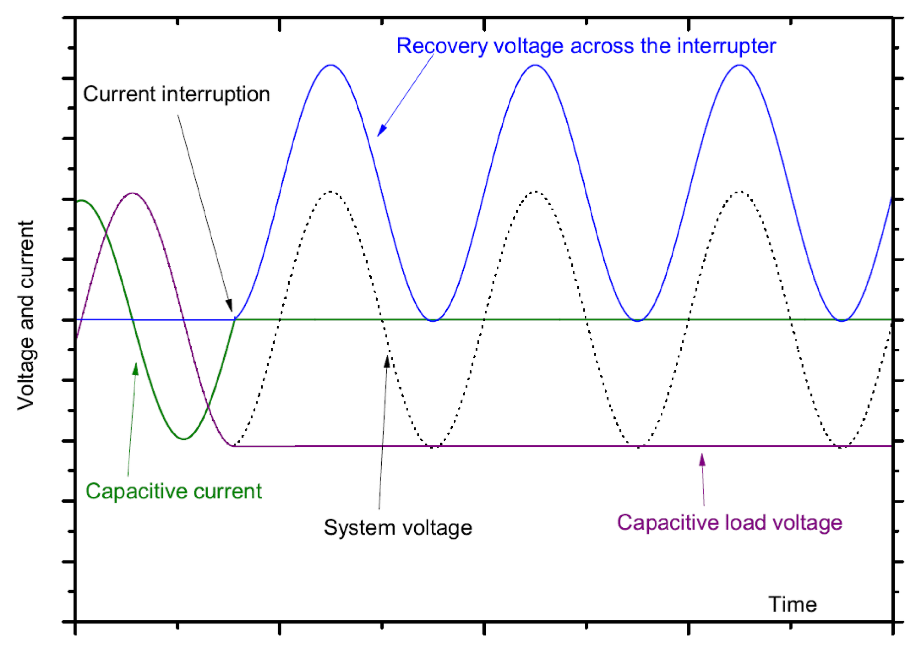
Working principle

- Contacts are opened at arbitrary time
- Vacuum arc is formed between the contacts
- Arc is extinguished at next current zero
- Recombination of plasma
- (Fast) Dielectric recovery

Technical Data [2]

- Lifetime: > 25 years
- Rated voltage: up to 52 kV
- Rated normal current: up to 6,3 kA
- Short-circuit breaking current: up to 72kA
- Gap distance: up to 25 mm

Re-Strikes and the Difficulties with Capacitive Loads



U-I-plots at capacitive current interruption [1]

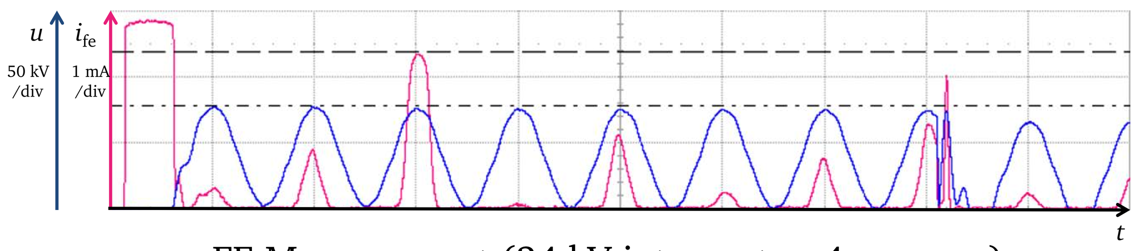
Capacitive load causes the highest dielectric stress for a VI:

- Re-Strikes of "unknown" origin occur
- Higher risks at higher voltages
- A capacitive load at least doubles the recovery voltage

Experience from Medium Voltage Tests

Field Emission

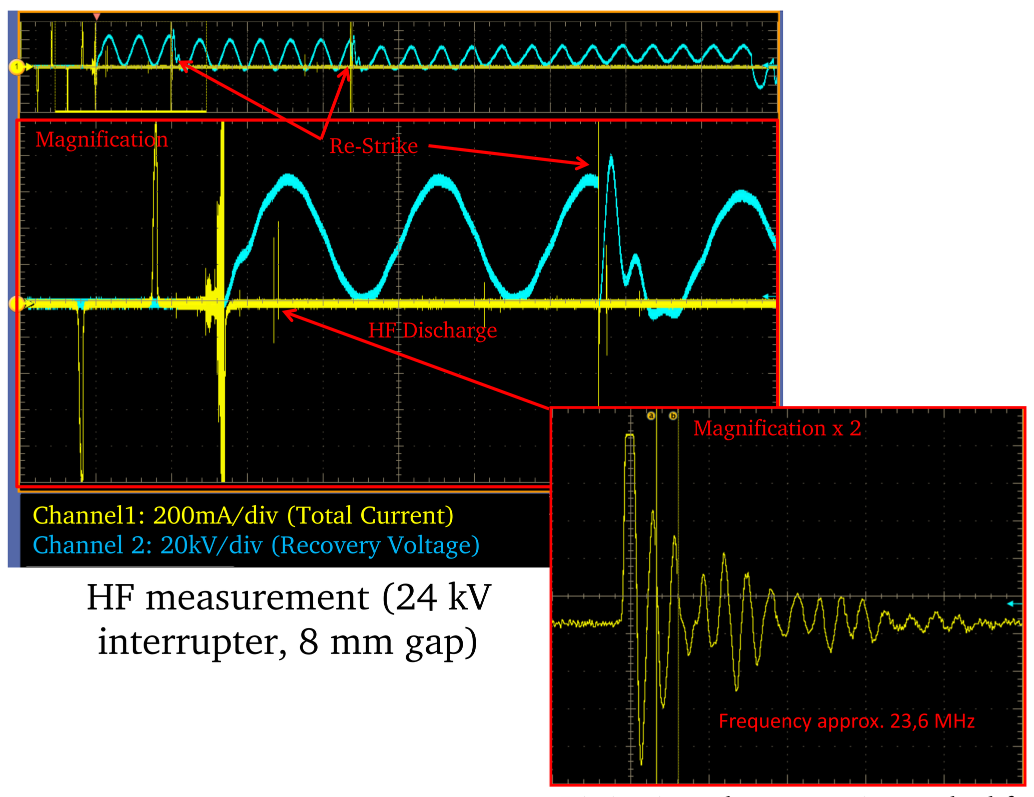
- Amplitudes in μA…mA range arise during TRV [1], [3]
- Oscillations in the amplitude [1]



FE Measurement (24 kV interrupter, 4 mm gap)

Micro-Discharges (-Particles)

- Particles are present in any vacuum interrupter [3]
- Correlation with manufacturing process [1]
- Correlation with mechanical shocks [4]



HF measurement (24 kV interrupter, 8 mm gap)

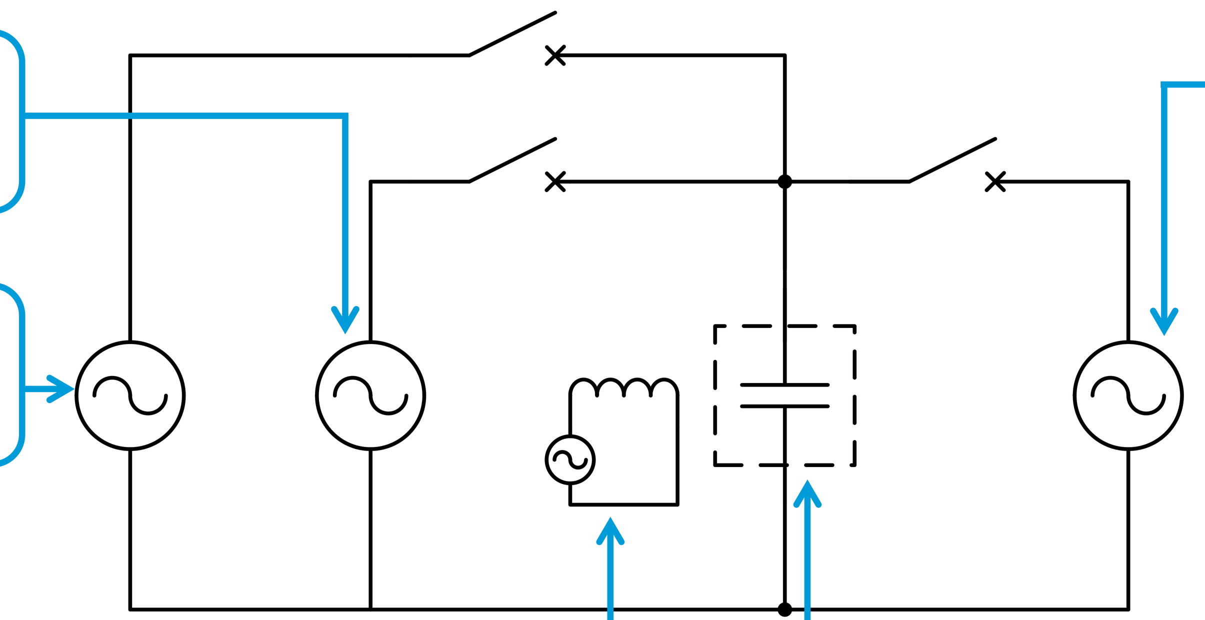
Distinction between internal hf discharge and external electromagnetic interference by evaluating envelope and frequency

Experimental Setup

Making Current
Up to 30 kA; 4,25 kHz

Breaking Current
2 kA; 50 Hz;
variable arcing time

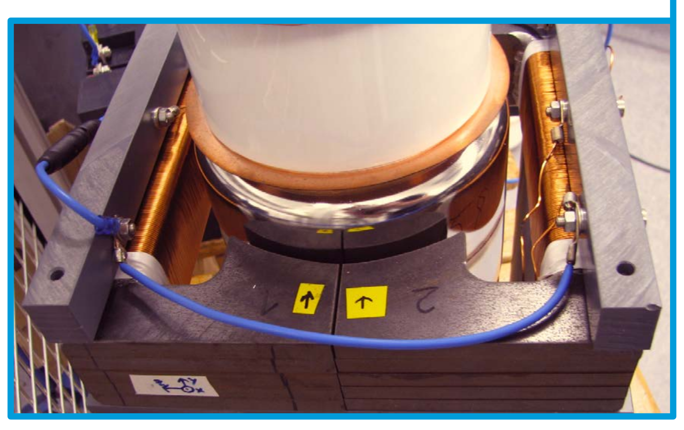
Recovery Voltage
(200 kV; "1-cos")



Test Procedure

Making Current → Breaking Current → Recovery Voltage (After x rounds)

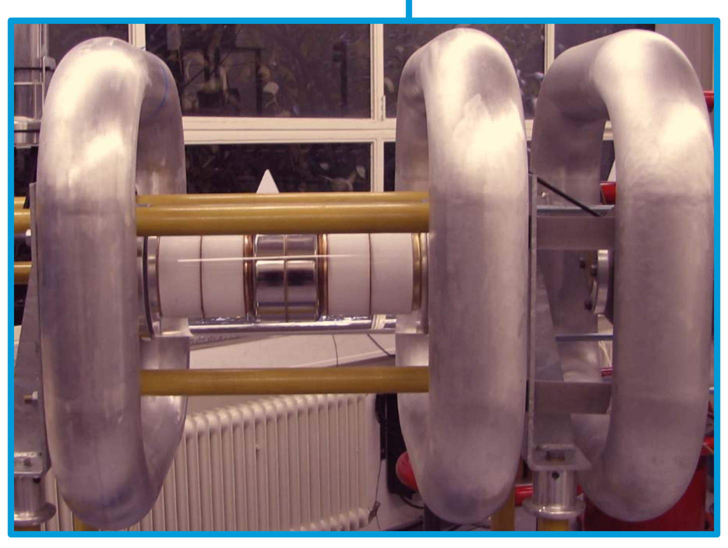
Measurements
Introduced Energy
Field Emission
HF Discharges
Gap Distance
Force
Voltage



Magnetic Insulation

In order to separate particles and electrons in the emission current and to mitigate the effects of an electron beam at the anode [5], a magnetic field is applied across the VI's contacts.

Current Design: min. 66 mT



Test Platform

- Specimen: 72,5 kV commercial VI (project partner: Siemens AG)
- External insulation: FC-40
- Variable gap distance up to 40 mm
- Switching velocity: 0,2 – 2 m/s
- Contact force: up to 3 kN

References

[1] M. Koochack-Zadeh. *Field Emission Current Analysis for the Assessment of Dielectric and Switching Performance of Vacuum Interrupters.* Phd thesis, TU Darmstadt, 2011

[2] Siemens AG. *Vakuum-Schalttechnik und Komponenten für die Mittelspannung, Ihr Wegweiser.* HG 11.01, 2007

[3] P.G. Slade. *The Vacuum Interrupters: Theory, Design, and Application.* CRC Press, Boca, Raton, London, New York, 2008

[4] R. Gebel, W. Hartmann. *Mechanical Shocks as Cause of Late Discharges in Vacuum Circuit Breakers.* IEEE Transaction on Electrical Insulation, Vol. 28 No. 4, August 1993

[5] Z. Kolaczkowski et. al. *Application of a Magnetic Field to Analyze the Prebreakdown Current in Vacuum Insulation.* IEEE Transactions on Electrical Insulation, Vol 24 No. 6, December 1989

Goals

- Design of a new test circuit for continuous study of dielectric breakdown.
- Verify the knowledge gathered in medium voltage level.
- Quantify the dielectric breakdown by simultaneous measurement of field emission and hf-discharges in the presence or absence of a magnetic field.