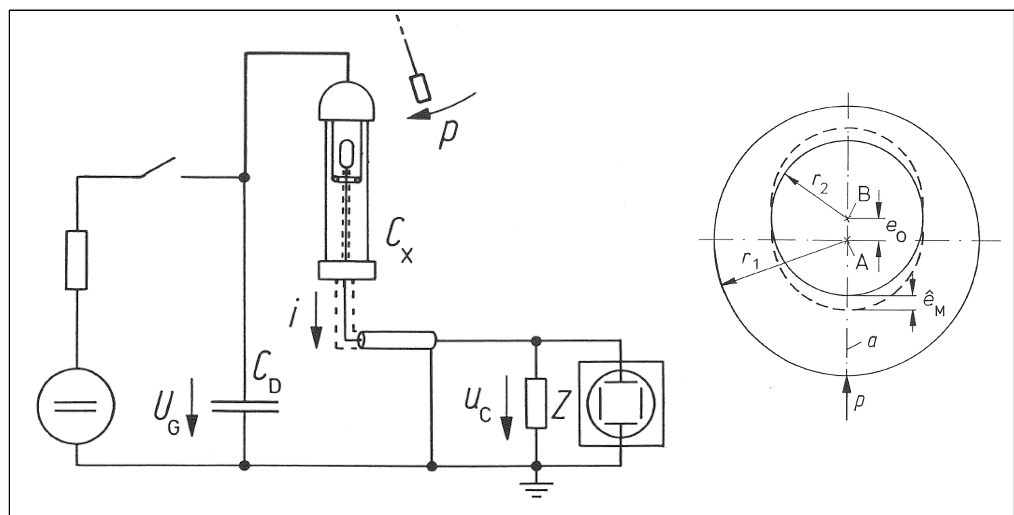
I. Introduction

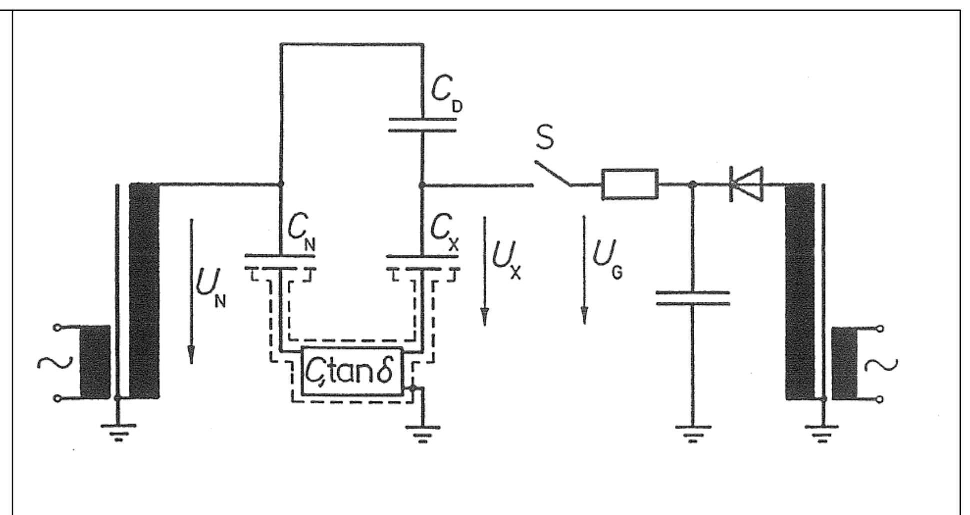
At National Metrology Institutes (NMIs) the traceability for high voltage transformers is given with the aid of high voltage compressed gas capacitors. The initial measurement of the capacitance is usually carried out at low voltages with the aid of capacitance bridges and transfer standards, which are in turn calibrated against primary references. For high voltages, the knowledge about the voltage dependency is essential. The focus of this work is the voltage dependency of high voltage capacitors and a new method for the determination of it.

II. Traditional Methods

In order to determine the voltage dependence of a high-voltage capacitor by means of a measuring bridge, a reference capacitor is required whose voltage dependence is known. Among others, the tilt method [Slomovitz 2019], the mechanical impulse method [Latzel 1989] and the 2-frequency method [Latzel 1989] are known.



Mechanical impulse method [Latzel 1989]



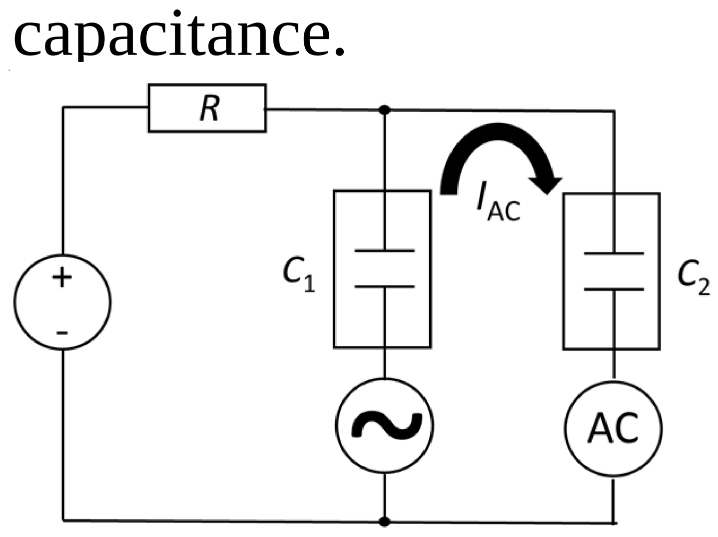
Direct voltage method [Latzel 1989]

It has become apparent that all methods agree in the range of a few ppm, but the circuits always contain additional components that have an influence on the determination of the voltage dependence. This disadvantages mean that there is no simple and at the same time unambiguous metrological traceability of high-voltage capacitors at high voltages. For this reason, a new method was investigated.

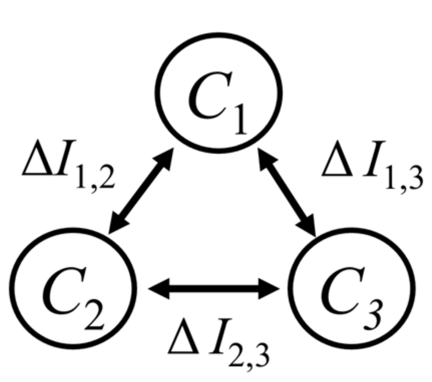
III. PRINCIPLE OF THE METHOD

This method uses a very stable low AC voltage with a frequency in the kHz range as a sense voltage. The application of a high DC voltage leads to a variation of the capacitance, which is noticed by a change in current due to the change in impedance of the capacitance.

The constant AC current flows mainly through the AC current meter and the capacitors C_1, which is the device under test, and C_2. The voltage dependency of this second capacitor is unfortunately also not known. But the relative change of the AC current at different DC voltages caused by both capacitors can be measured.



$$\Delta I_{AC}(U_{DC}) = \frac{U_{AC}}{\frac{1}{j\omega\Delta C_{1,DC}} + \frac{1}{j\omega\Delta C_{2,DC}}}$$

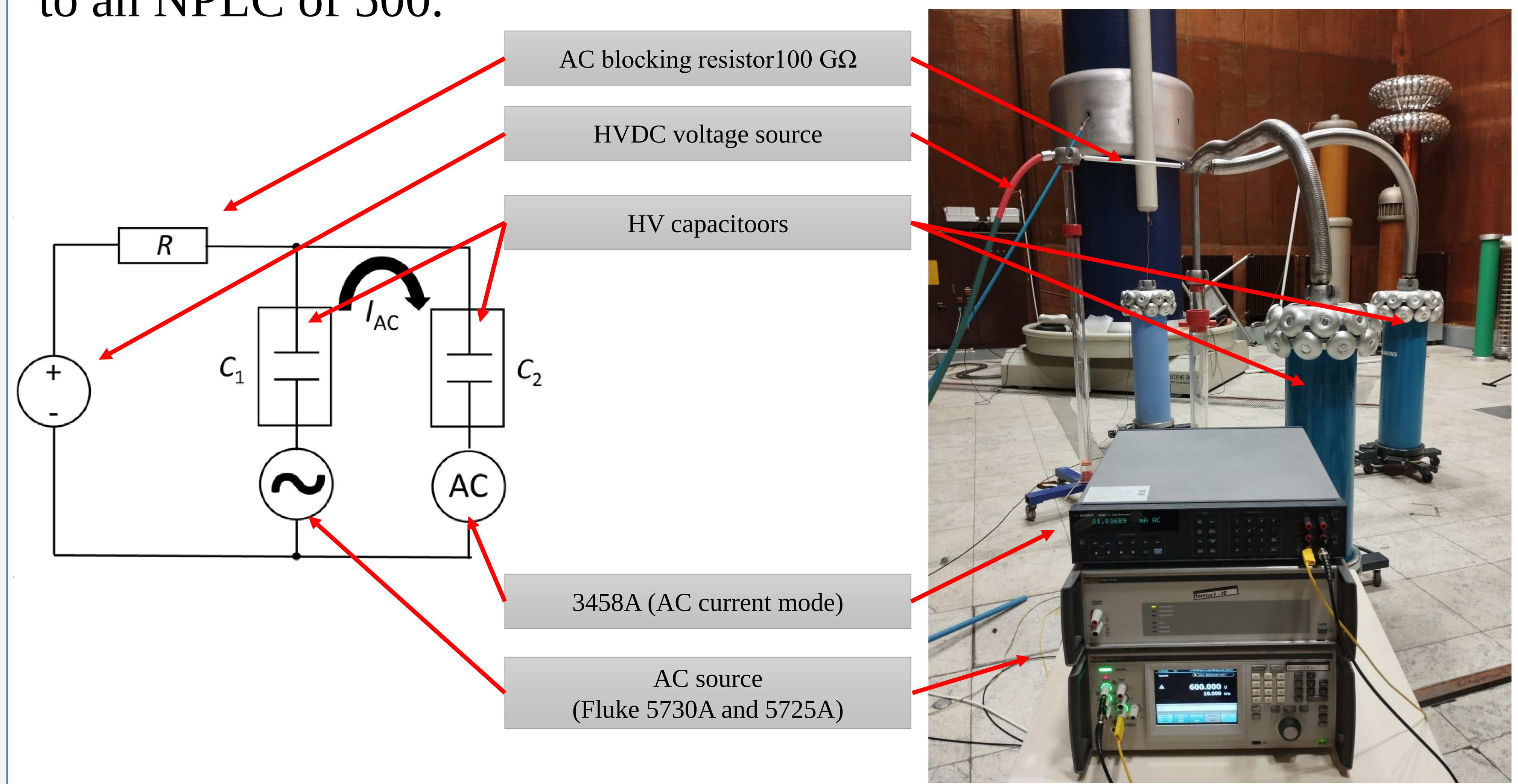


Using a third capacitor three measurements can be done with three DC voltage dependent current changes and three unknown capacitance changes. Here the shown Δ*I* is the AC current change caused by the change in capacity due to the DC voltage.

$$\Delta I_{1,2}(U_{DC}) = \frac{U_{AC}}{\frac{1}{j\omega\Delta C_{1,DC}} + \frac{1}{j\omega\Delta C_{2,DC}}} \qquad \Delta I_{2,3}(U_{DC}) = \frac{U_{AC}}{\frac{1}{j\omega\Delta C_{2,DC}} + \frac{1}{j\omega\Delta C_{3,DC}}} \qquad \Delta I_{3,1}(U_{DC}) = \frac{U_{AC}}{\frac{1}{j\omega\Delta C_{3,DC}} + \frac{1}{j\omega\Delta C_{1,DC}}}$$

IV. MEASUREMENT SETUP AND RESULTS

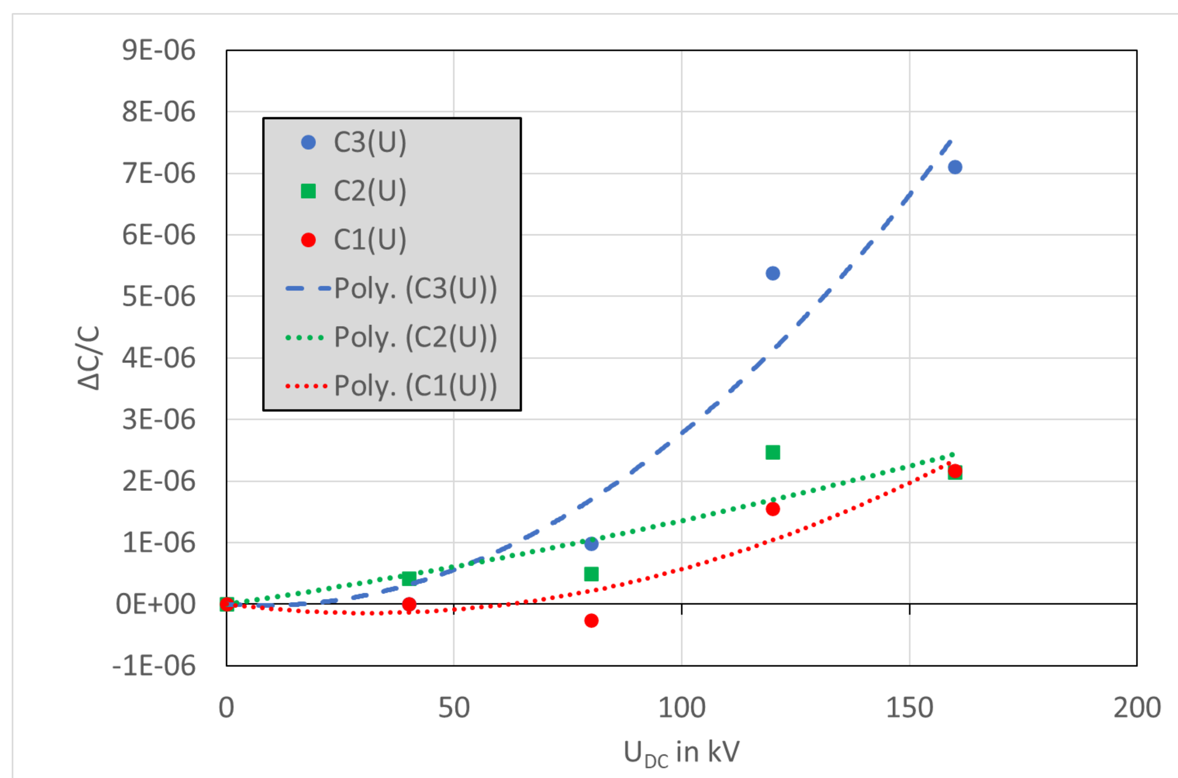
Three identical compressed gas capacitors MCP200 with a rated voltage of 200 kV and 100 pF where used. DC Voltages from 0 V to 160 kV were applied to each pair of capacitors in 40 kV steps. A resistor of 100 GΩ was used to block the HVDC source from the circuit. An AC voltage of 600 V_{RMS} at a frequency of 10 kHz was generated using a Fluke 5730A with a Fluke 5725A. The current through the two capacitors was measured using a 3458A multimeter set to an NPLC of 500.



$$\Delta C_{1,DC} = \frac{2 \cdot \Delta I_{1,2} \cdot \Delta I_{3,1} \cdot \Delta I_{2,3}}{U_{AC} \cdot 2\pi f \cdot (\Delta I_{1,2} \cdot \Delta I_{2,3} - \Delta I_{1,2} \cdot \Delta I_{3,1} + \Delta I_{3,1} \cdot \Delta I_{2,3})}$$

$$\Delta C_{2,DC} = \frac{2 \cdot \Delta I_{1,2} \cdot \Delta I_{2,3} \cdot \Delta I_{3,1}}{U_{AC} \cdot 2\pi f \cdot (\Delta I_{2,3} \cdot \Delta I_{3,1} - \Delta I_{2,3} \cdot \Delta I_{1,2} + \Delta I_{1,2} \cdot \Delta I_{3,1})}$$

$$\Delta C_{3,DC} = \frac{2 \cdot \Delta I_{1,2} \cdot \Delta I_{2,3} \cdot \Delta I_{3,1}}{U_{AC} \cdot 2\pi f \cdot (\Delta I_{3,1} \cdot \Delta I_{1,2} - \Delta I_{3,1} \cdot \Delta I_{2,3} + \Delta I_{2,3} \cdot \Delta I_{1,2})}$$



The measured currents, which are dependent on the DC voltage were used to calculate the voltage dependency of the capacity by solving the equations to ΔC_n and eliminate the other both ΔC.

The results are plotted and highlighted using polynomial fits of 2^{nd} grade.

V. CONCLUSION

The presented method of determining the linearity of high-voltage capacitors can be used rapidly and in the uncertainty range of a few ppm. The clear benefit of this method resists in the fact, that neither the capacitors, nor any exact voltages or currents have to be known. Additionally, all capacitor types can be tested, unlike the tilting method, which is only suitable for capacitor types with a cylindrical central electrode. The drawbacks are that always three capacitors are required, which should have the same order of magnitude of voltage dependency. In the future, this method will be compared with the existing methods, e.g. the tilting of compressed gas capacitors.

VI. ACKNOWLEDGEMENT

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EMPIR EURAMET

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[Slomovitz 2019]: Daniel Slomovitz, et al. "Determination of Voltage Dependence in High-Voltage Standard Capacitors", IEEE transactions on instrumentation and measurement, vol. 68, no. 6, June 2019

[Latzel 1989]: Latzel, H.-G. "Über den Einfluss von Spannung und Frequenz auf die Kapazität von Hochspannungs-Druckgaskondensatoren", Dissertation, TU Braunschweig, 1989