8. Dielectric Loss Angle

SAFETY MEASURES: Interlocks are provided to prevent high voltage to be switched on while the gates/ doors are open. Despite these measures it is necessary to connect the safety earth stick to the HV parts before touching. (There could be some charge left on the capacitors). Special safety rules for the High Voltage laboratory must be read, understood, signed and always followed to every detail!

8.1 Objectives

The student must gain the following knowledge and comprehension in the following topics:

- General description of the non-destructive high voltage test method: Schering-bridge.
- Assessment of the capacitance, C_x, and the dissipation factor, *tan* δ_x: ABB inductive voltage transformer.
- Assessment of the capacitance, C_x, and the dissipation factor, *tan* δ_x: ideal homemade capacitor.

8.2 General Description: Schering-bridge

The loss factor or dissipation factor, *tan* δ, is an indicator of the quality of solid or liquid dielectrics. In order to measure the capacitance and dissipation factor, *tan* δ, a non-destructive test is performed with the high voltage Schering-bridge, which schematic is shown in Figure 1 and the test equipment is shown in Figure 2. Such tests are usually carried out at different voltage levels in order to ensure that **both capacitance and dissipation factor are constant,** i.e., linear with respect to voltage. The Schering-bridge adjusts the resistance and capacitance values automatically. In case that some deviations are observed when measuring the loss angle at different applied voltage levels; two possible explanations can be given: i) non linearity of the system (please explain this with the polarization processes as being non-linear), ii) indication of partial discharges.

The Schering-bridge is based on the fact that whenever there is the same voltage across the two mid-points of the bridge (this is Vb = Vd), the loads can be related following the next equation:

$\frac{Zab}{Zbc} = \frac{Zad}{Zdc}$ where $Zad = Rs + {}^{1}/_{jwCs}; Zab = {}^{1}/_{jwCn}; Zbc = \frac{1}{{}^{1}/_{R4} + jwC4}; Zdc = R3$

With this information, it is also possible to obtain $Cs = Cn * \frac{R4}{R3}$ and $Rs = R3 * \frac{C4}{Cn}$.

Finally since both the active and reactive loads are known, we can calculate $\tan\delta$ as:
$\tan\delta = w * Rs * Cs = w * R4 * C4$ and also $\mathrm{P} = \tan\delta * Q$

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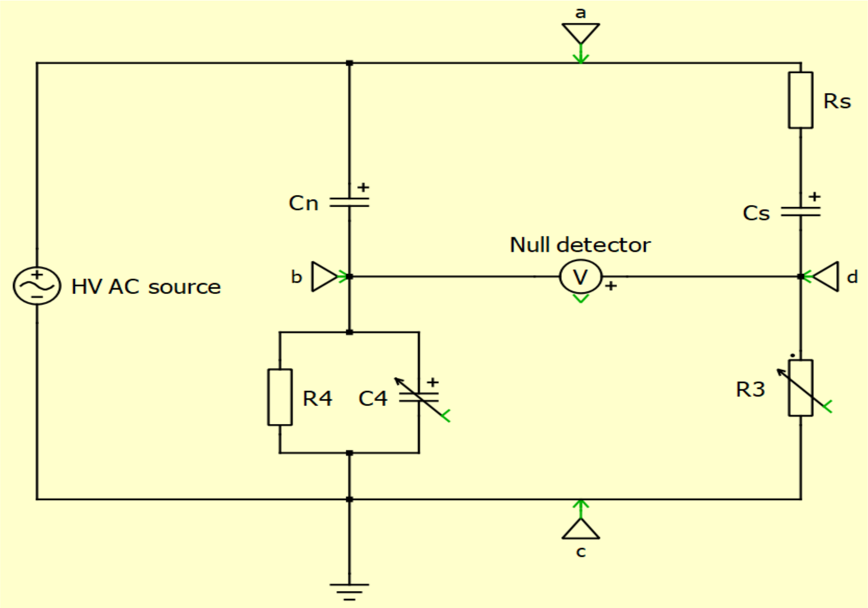
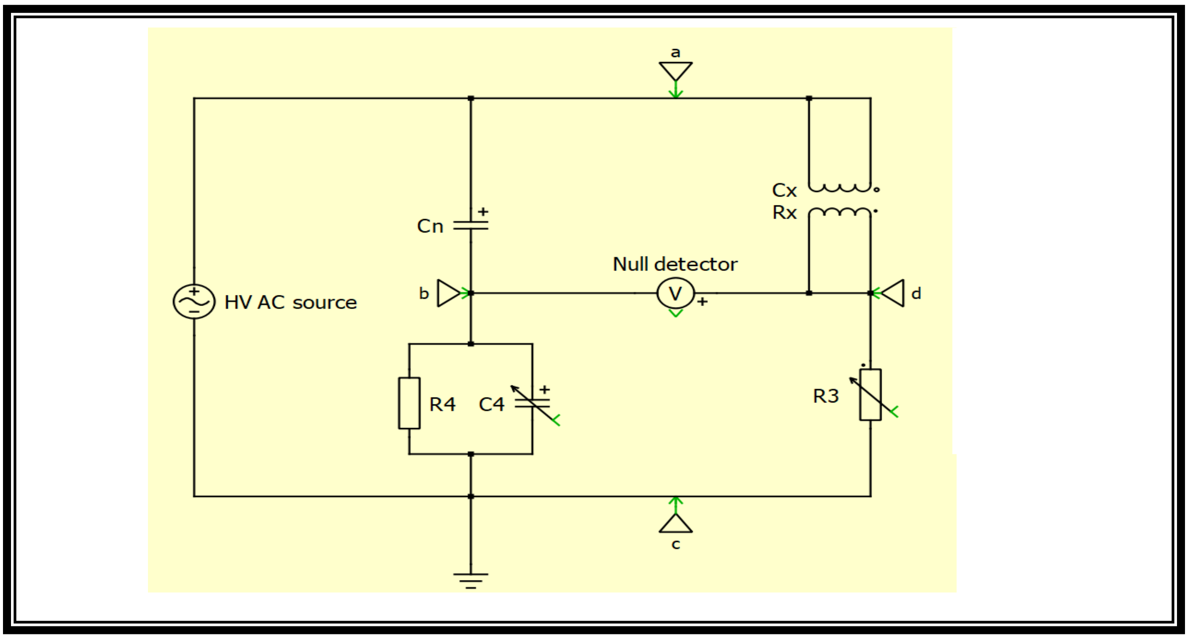


8.3 ABB Inductive Voltage Transformer

8.3.1 Setup Description

During the first experiment, the capacitance and the loss angle of the 60 kV ABB inductive voltage transformer EMF (EMF 52-170) will be measured. The test object is connected between the **primary terminals** (High Voltage side, point (a) from Figure 1) and the **secondary terminal** (point (d) from Figure 1). The normal capacitor, C_N, consists of a pressurized gas capacitor which represents an ideal capacitor, therefore it can be assumed that $\varphi_N = 0$. The low voltage branch is included inside the measuring equipment (capacitance and *tan* δ measuring bridge).



8.3.2. Results and discussions

The 60 kV inductive voltage transformer must be tested at different voltage levels in a range between $0\ kV - \frac{60}{\sqrt{3}}$ kV.

V [kV]	C_x [pF]	$\tan\delta_x$	δ_x [º]	I [µA]
1.5	686	0.021	1.203	337
2.0	686	0.021	1.203	440
2.5	686	0.021	1.203	559
3.0	686	0.0214	1.226	670
4.0	686	0.0215	1.232	885
4.5	686	0.0218	1.249	993
5.0	687	0.0219	1.255	1102

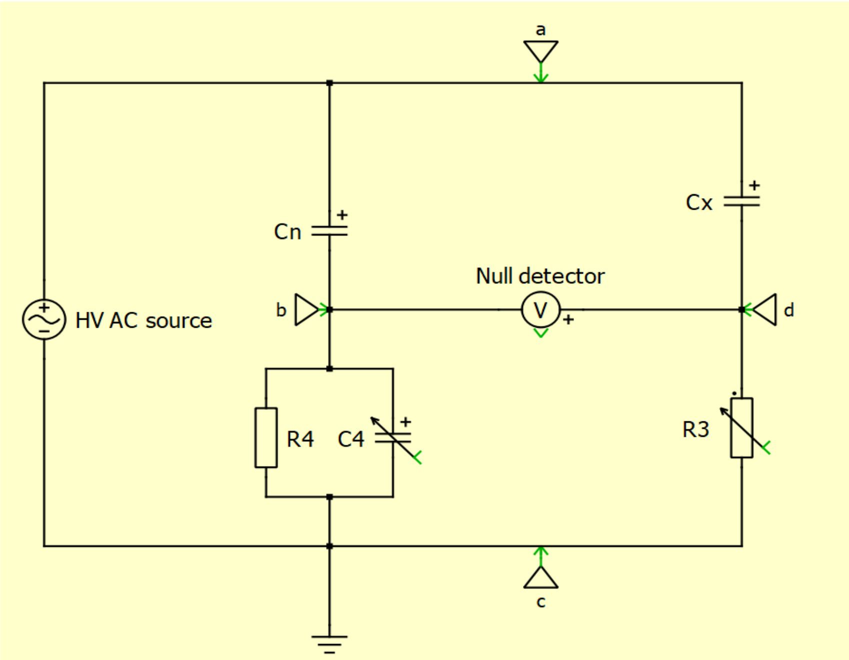
The results obtained are according to the expected since constant values are obtained. Voltage difference should not make a difference in the capacitance obtained as well as in $\tan\delta$.

It is clearly shown how the capacitance is constant (less than 0.15% change) as well as the losses ($\tan\delta$ is also almost constant).

8.4 Homemade Capacitor

8.4.1 Setup Description

During the third experiment, the inductive voltage transformer will be replaced with a homemade capacitor which is purely capacitive. The purpose is to conclude with a clearer idea of the experimental setup and understand the fundamental principle of the Schering-bridge.

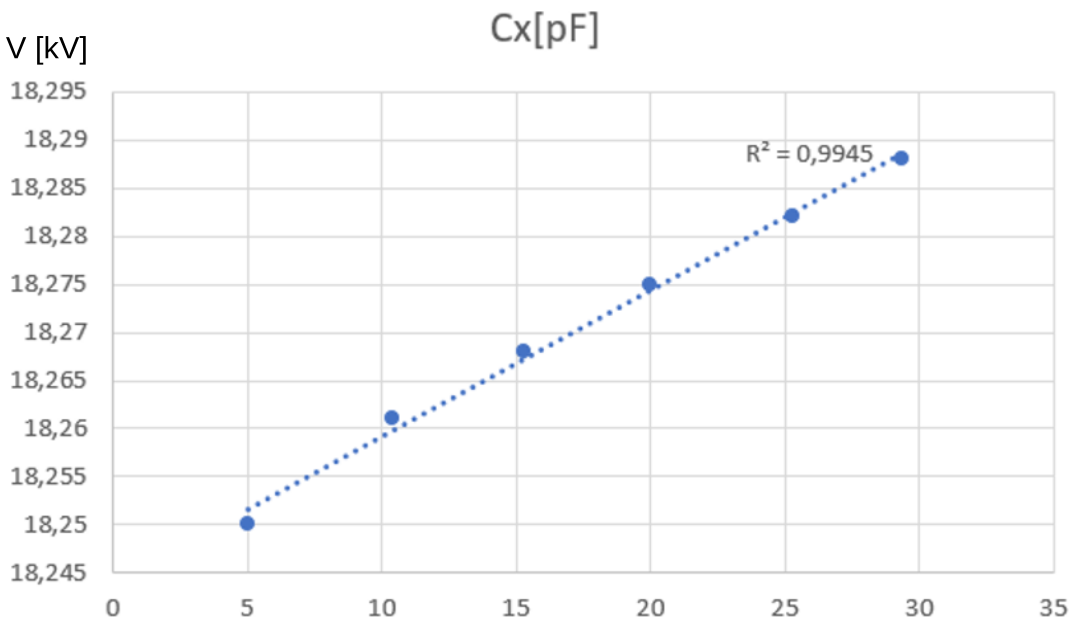


8.4.2 Results and Discussions

The homemade capacitor must be tested at different voltage levels, in a range between 0 kV – 25 kV.

V [kV]	C_x [pF]	$\tan\delta_x$	δ_x [º]	I [µA]
5.0	18.25	0.0323	1.850	29.8
10.4	18.261	0.0336	1.924	59.9
15.32	18.268	0.0345	1.976	88.1
20.28	18.275	0.0354	2.027	115.1
25.28	18.282	0.0362	2.073	145.4
29.35	18.288	0.0365	2.090	168.6

We can also see that the results obtained with the home-made capacitor are quite similar although not as similar as those obtained in the previous experiment. We can also see the behavior of the insulation material with respect to the voltage applied in the following graph.



It is clearly shown how the capacitance of the home-made capacitor is linear with an almost perfect fit. If this capacitor was replaced with a normal capacitor, its capacitance should not show dependence on the voltage applied.