DESCRIPTION OF 72 KV VOLTAGE TRANSFORMER & ASSESSMENT OF THE INSULATION QUALITY

HIGH VOLTAGE ENGINEERING
MINILAB

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CONTENT

DATA OF THE VOLTAGE TRANSFORMER

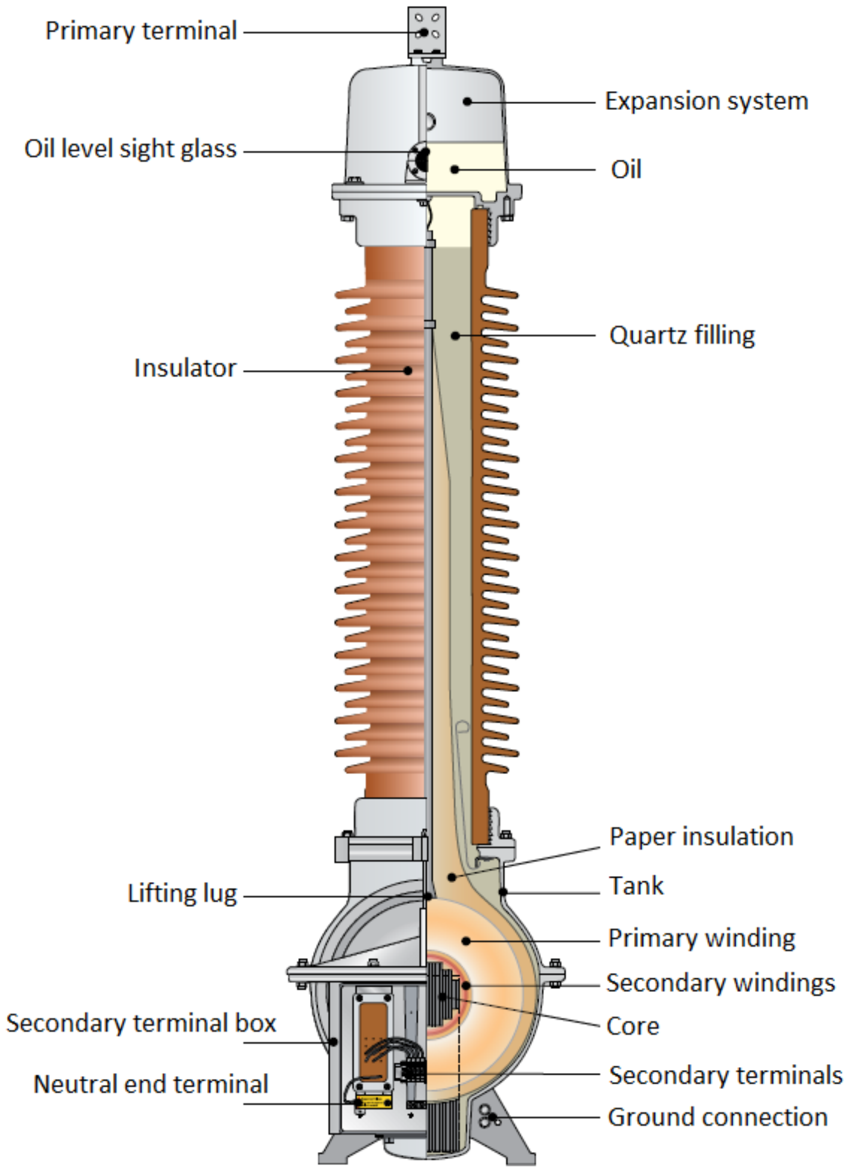


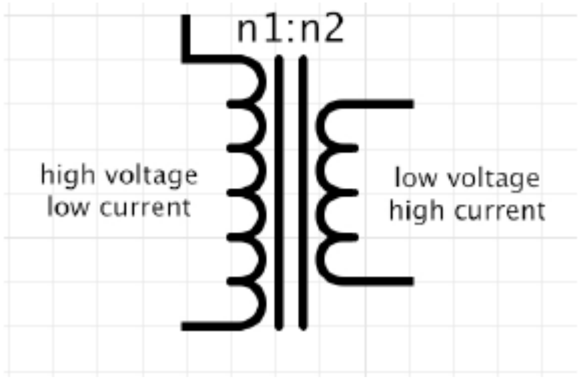
ABB EMF 72 kV
Inductive voltage transformer.

Rated primary voltage: 60/√3 kV
Rated secondary voltage: 100/√3 V

Insulation: oil-paper-quarz
Insulator: porcelain
Dielectric strength: 12 kV/mm
Creepage distance: 2248 mm

TRANSFER RATIO MEASUREMENT

- Performed at different primary voltage levels
  → under no load (no currents)
- Primary voltage supplied by capacitive voltage divider
- Secondary voltage measured by multimeter

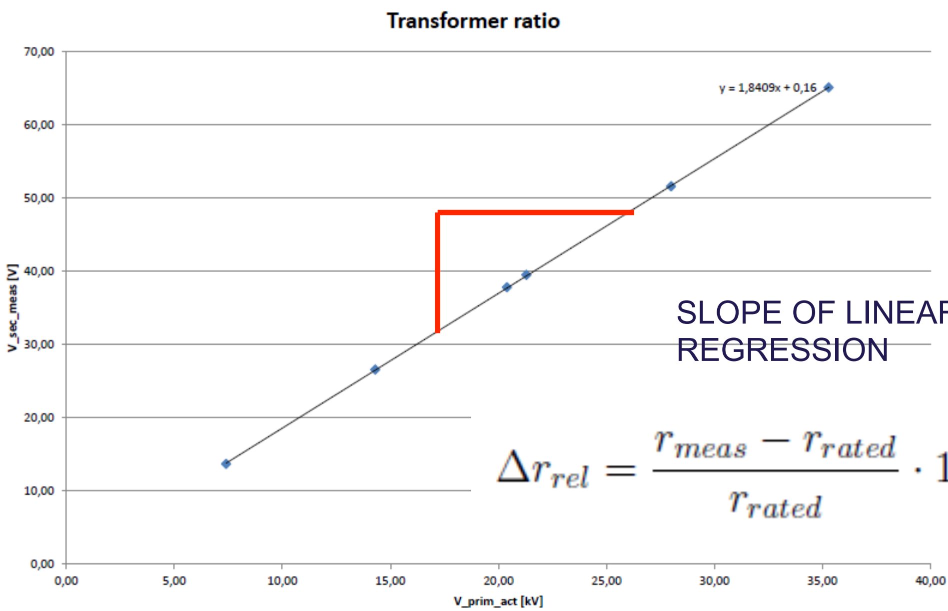


$$\frac{N_{primary}}{N_{secondary}} = \frac{V_{primary}}{V_{secondary}} = \frac{I_{secondary}}{I_{primary}}$$

- ABB voltage transformer: $r_{rated} = \frac{V_{pri}}{V_{sec}} = \frac{60\,kV}{110\,V} = 545.45$

TRANSFER RATIO MEASUREMENT

Steps	Vprimset[kV]	Vprimact[kV]	Vsecmeas[V]	Ratio	Abs Error	Rel Error(%)
1	7	7.40	13.65	542.12	-3.33	-0.61
2	14	14.30	26.55	538.61	-6.85	-1.26
3	20.4	20.40	37.80	539.68	-5.77	-1.06
4	21	21.30	39.50	539.24	-6.21	-1.14
5	28	28.00	51.60	542.64	-2.82	-0.52
6	35	35.30	65.10	542.24	-3.21	-0.59



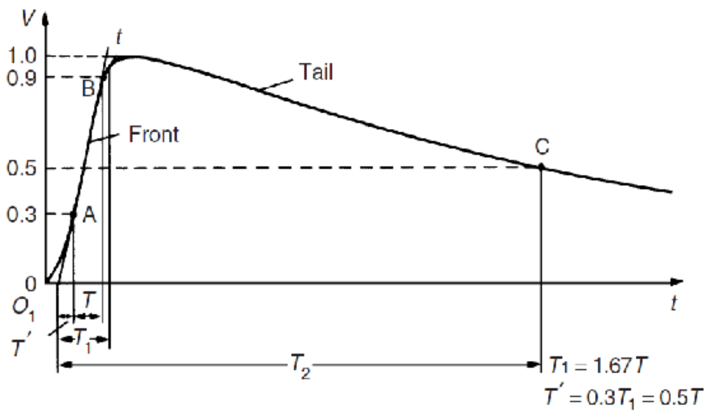
SLOPE OF LINEAR REGRESSION

$$r_{meas} = \frac{V_{pri}}{V_{sec}} = \frac{1}{slope \cdot 1000} = 543.21$$

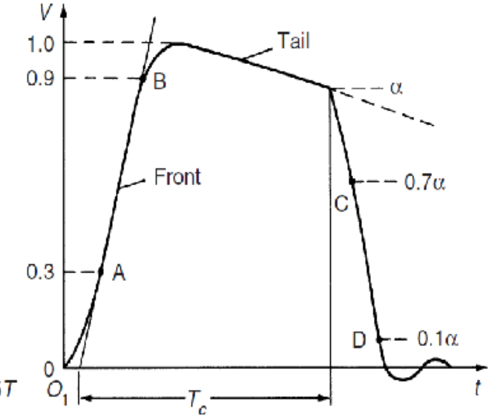
- Acceptable result!

$$\Delta r_{rel} = \frac{r_{meas} - r_{rated}}{r_{rated}} \cdot 100\% = \frac{543.21 - 545.25}{545.25} \cdot 100\% = -0.41\%$$

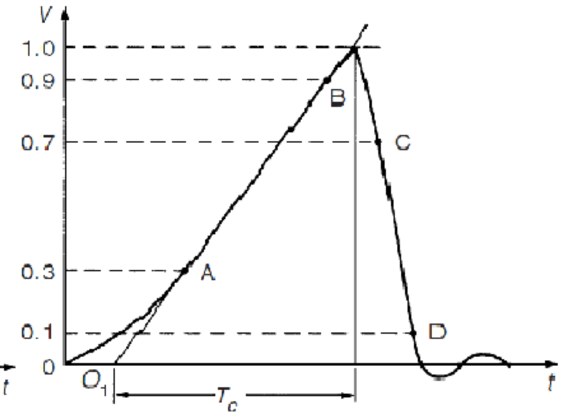
LIGHTNING IMPULSES



Full lightening impulse



Lightening impulse chopped on the tail

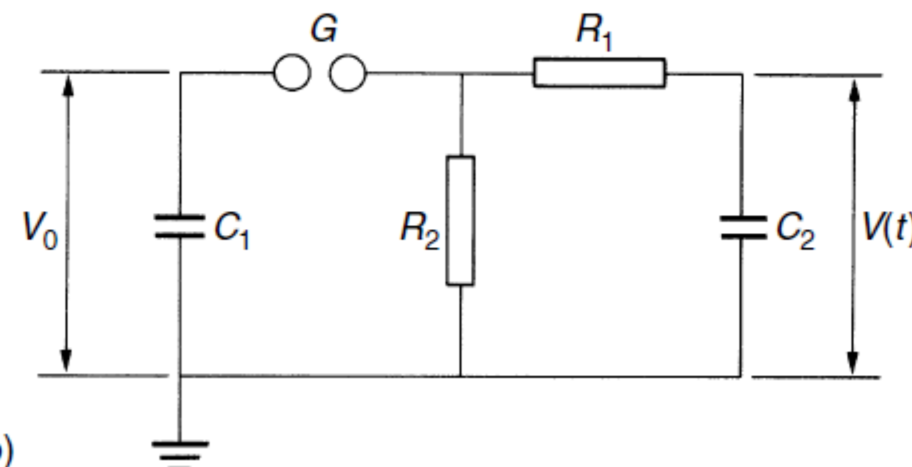


Lightening impulse chopped on the front

- unidirectional voltage
- rapid rise
- slow decay

- breakdown if insulation fails

- creation in lab with simple discharging circuit:



(b)

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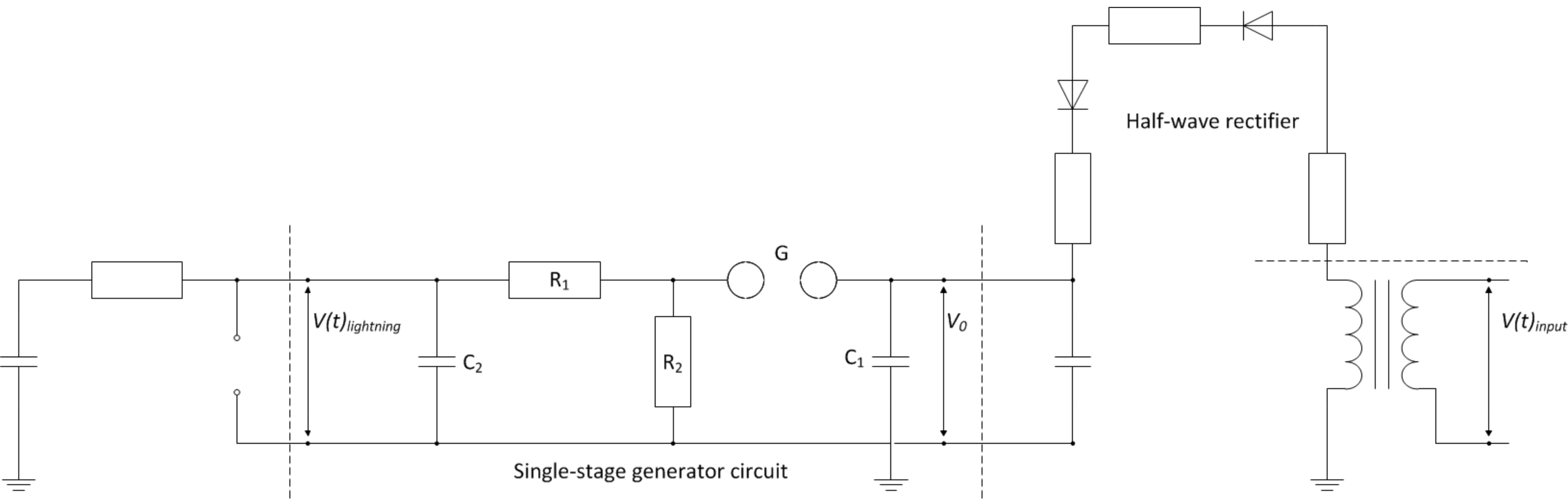
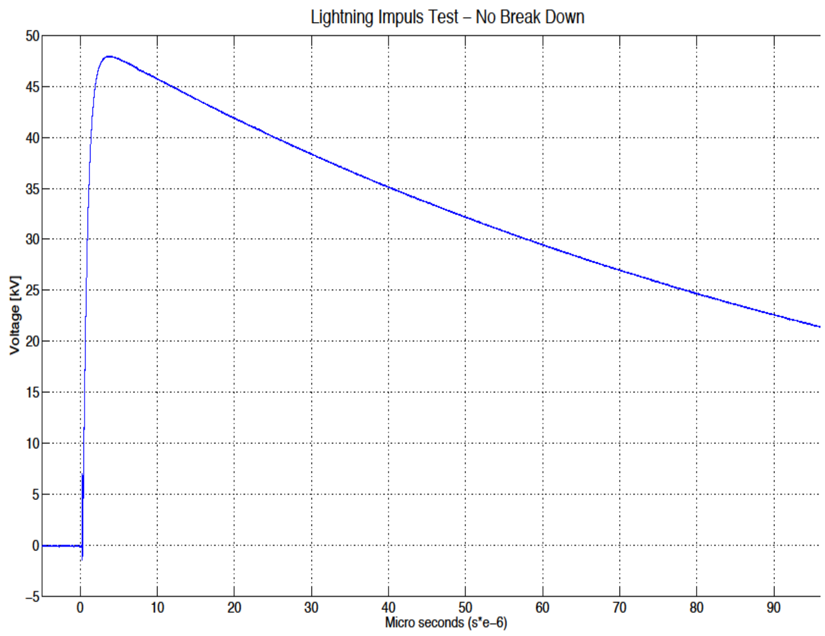
LIGHTNING OVERVOLTAGE TEST SETUP



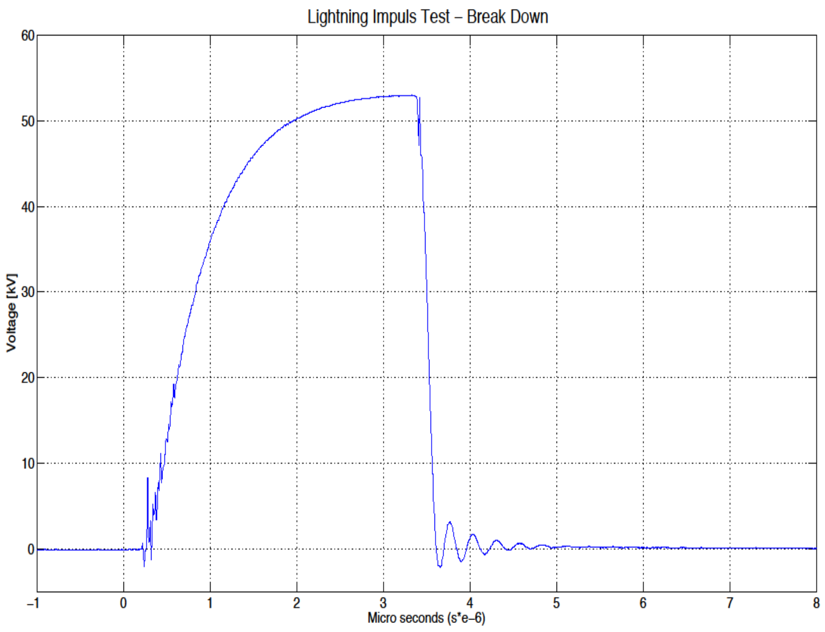
- AC voltage supply
- transformer
- half-wave rectifier
- discharging circuit
- test object
- low pass filter

LIGHTENING OVERVOLTAGE TEST RESULTS

- no breakdown

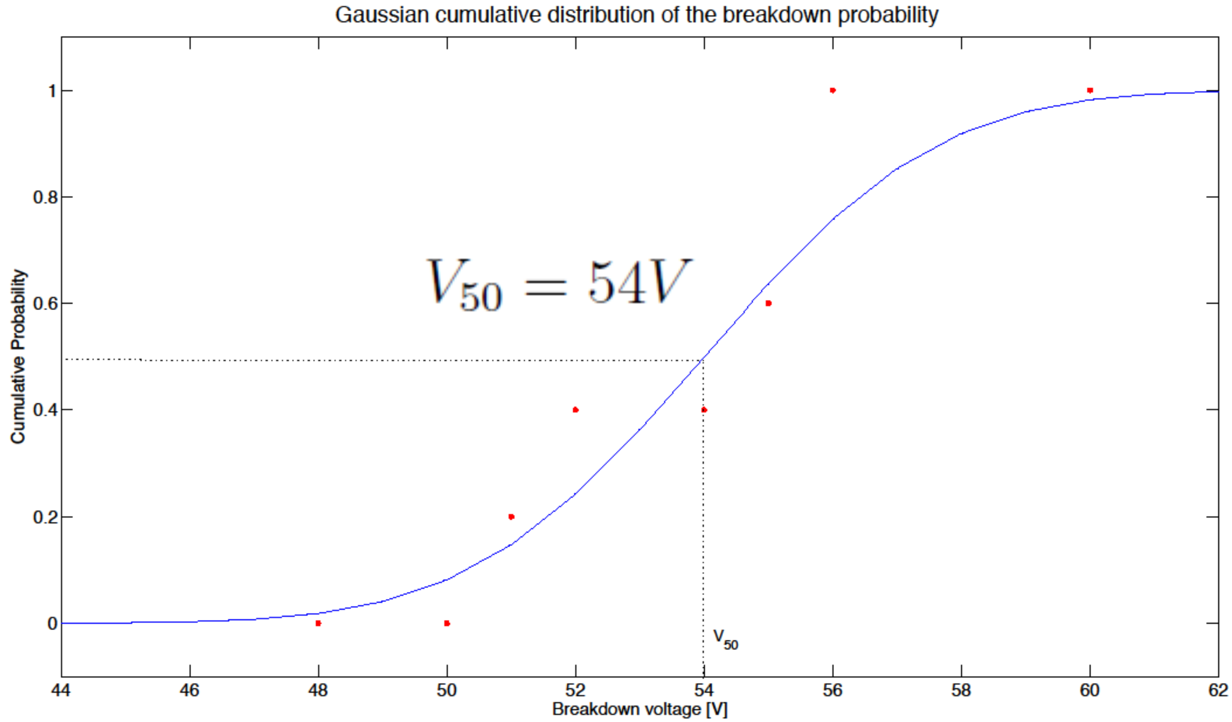


- breakdown



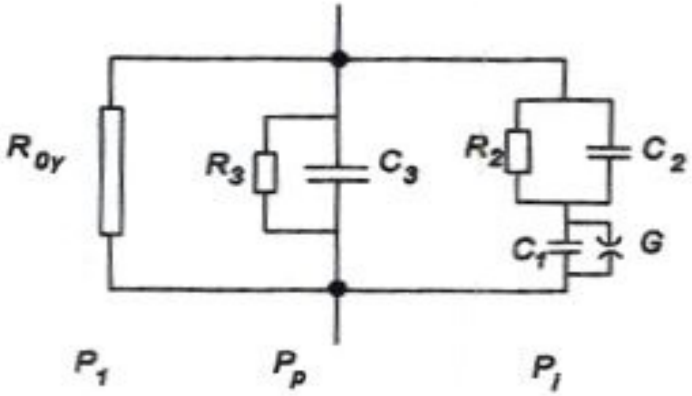
LIGHTENING OVERVOLTAGE TEST RESULTS

$$P(V) = \frac{1}{\sigma\sqrt{2\cdot\pi}} \int_{-\infty}^{\infty} e^{\frac{-(V-V_{50})^2}{2\sigma^2}} dx \qquad \sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(V - V_{50})^2} = 2,867kV$$



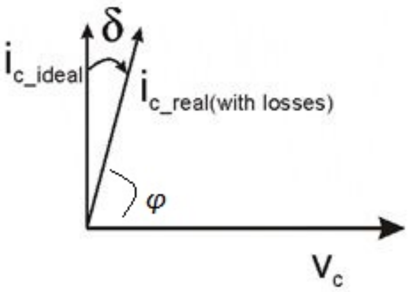
DIELECTRIC LOSS ANGLE MEASUREMENT

Dielectric Equivalent



$$P_{diel} = P_1 + P_p + P_i$$

Loss Angle δ



$$tan\delta = \frac{I_w}{I_{wl}} = \frac{P_{diel}}{Q}$$

$$P_{diel} = Q \cdot tan\delta = \omega \cdot C \cdot tan\delta \cdot V^2$$

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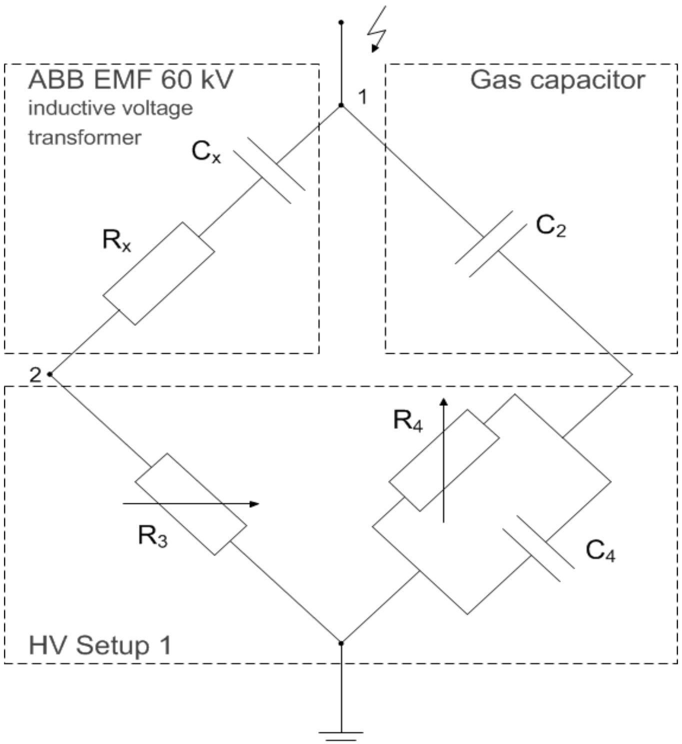
DIELECTRIC LOSS ANGLE MEASUREMENT

Schering Bridge method for Capacitance and Loss angle measurement



$$Z_x \cdot Z_4 = Z_2 \cdot Z_3$$

$$|Z_x| \cdot |Z_4| = |Z_2| \cdot |Z_3|$$

$$\varphi_x + \varphi_4 = \varphi_2 + \varphi_3$$

$$\varphi_4 = 90 - \varphi_x = \delta_x$$

$$C_x = C_2 \cdot \frac{R_4}{R_3 \cdot (1 + tan^2\delta_x)} = C_2 \cdot \frac{R_4}{R_3}$$

$$tan\varphi_4 = \omega \cdot R_4 \cdot C_4 = tan\delta_x$$

DIELECTRIC LOSS ANGLE MEASUREMENT

Lab Results

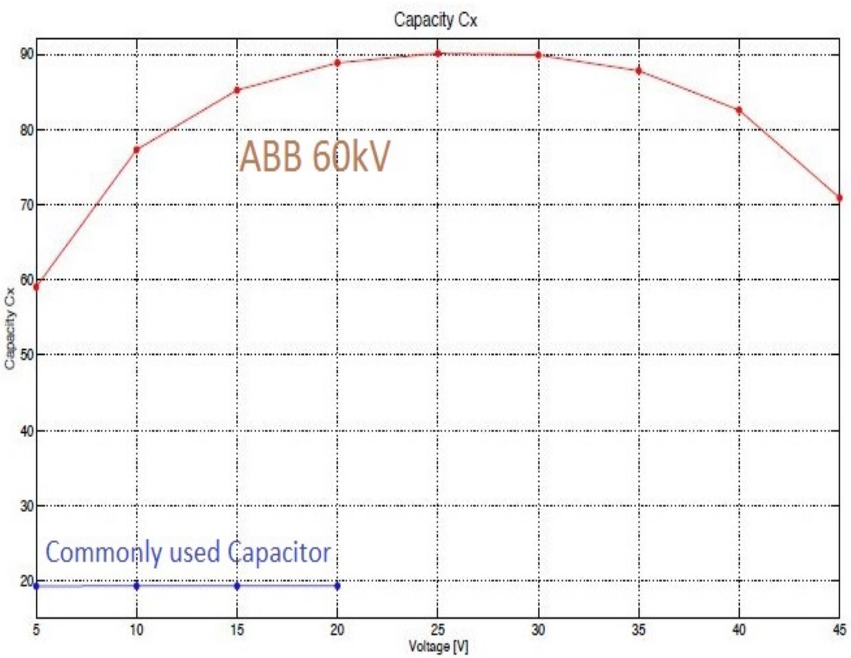


Fig. a: Measured Capacitance for different applied voltages

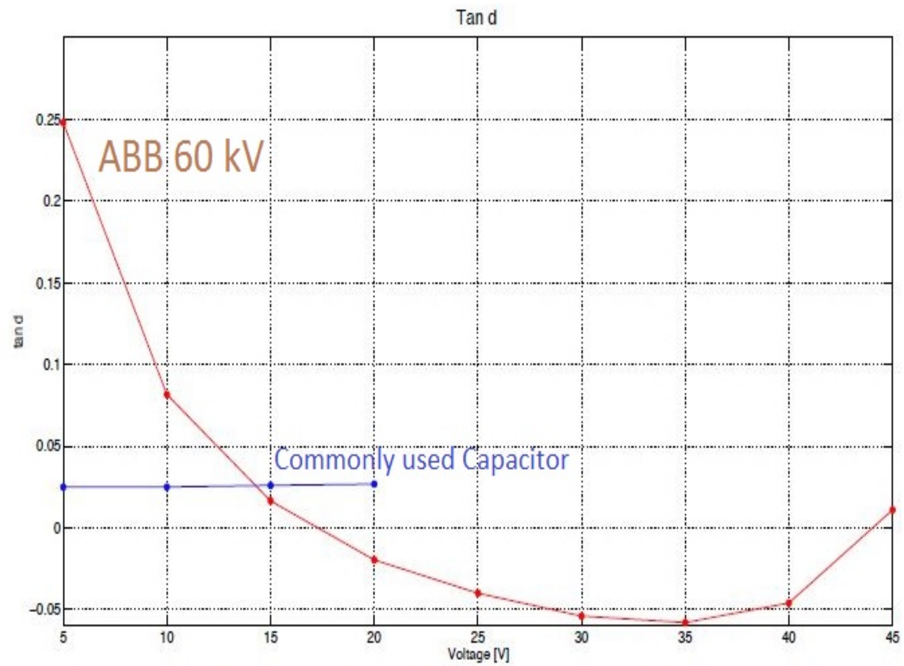


Fig. b: Measured $\tan\delta$ for different applied voltages

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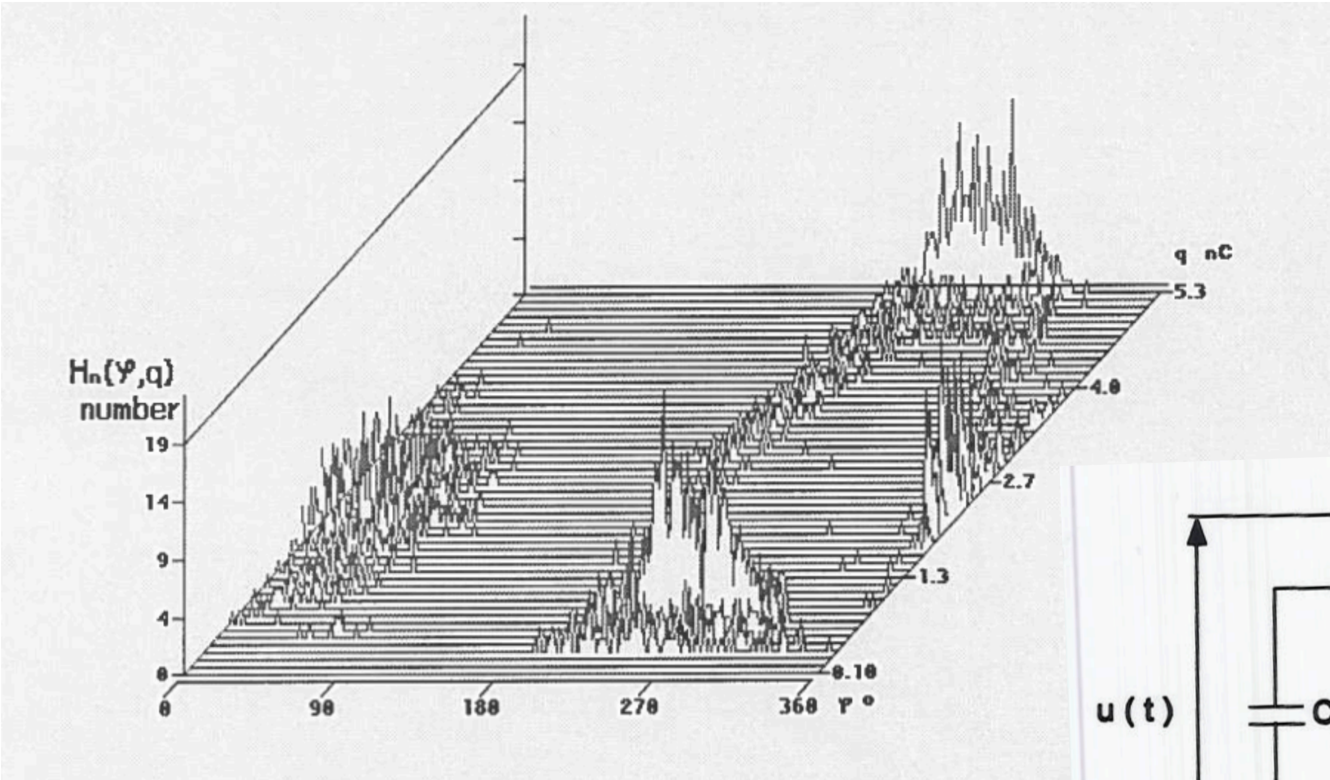
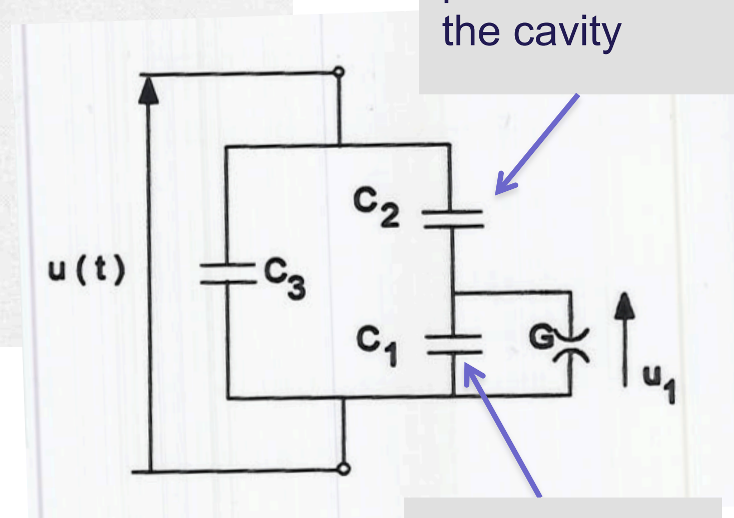
PARTIAL DISCHARGES (PD)

- External partial discharges
  - Inhomogenous field in a gaseous dielectric
    - → Corona
    - → Surface discharges

- Internal partial discharges
  - Discharges in a cavity of solid/liquid dielectric.

Internal Discharges

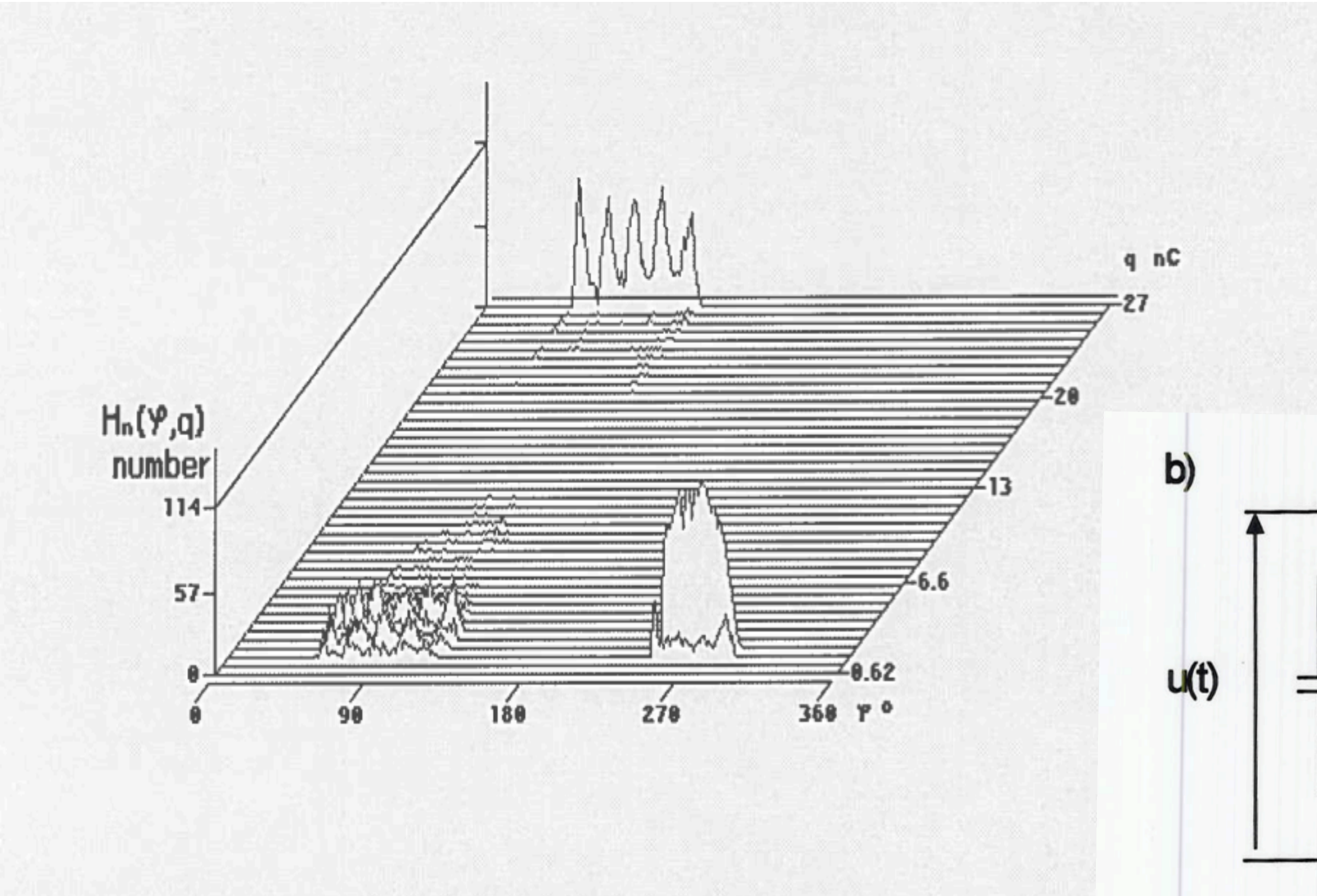


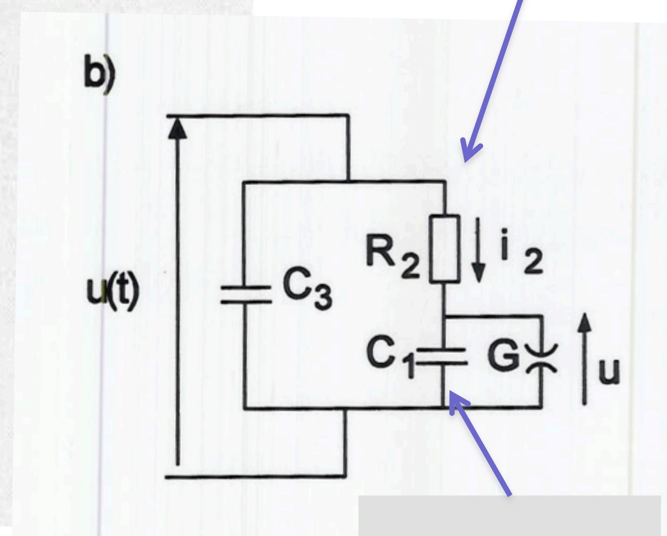


Capacitance of the ‘healthy’ part around the cavity

Capacitance of the cavity

External Discharges

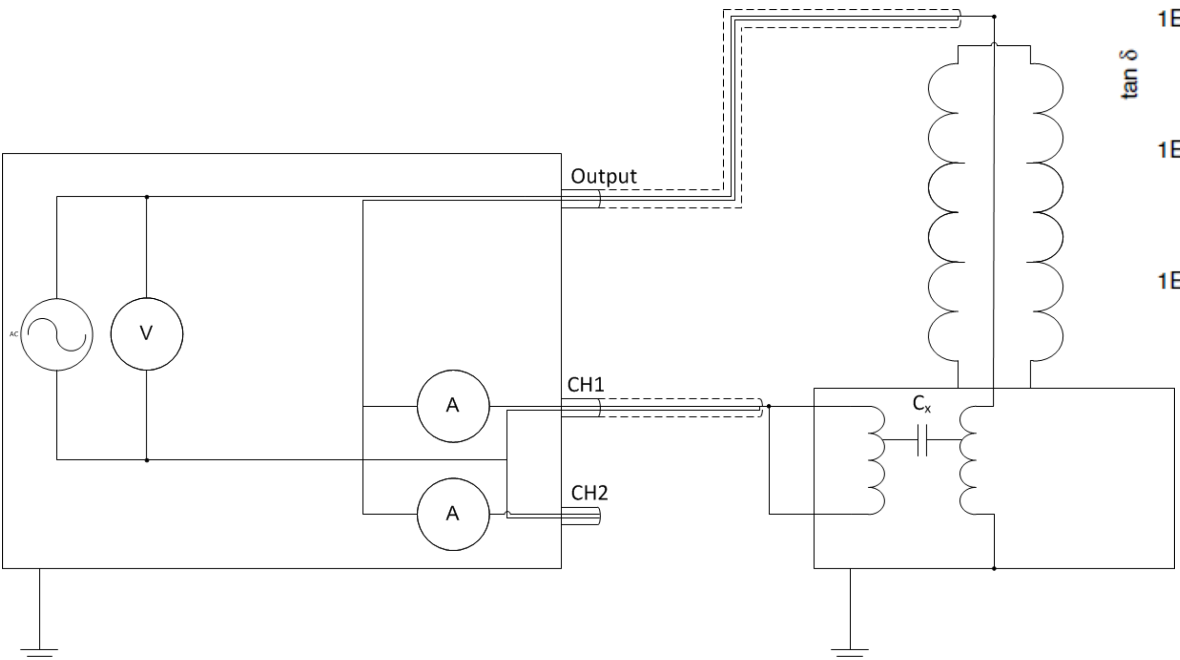


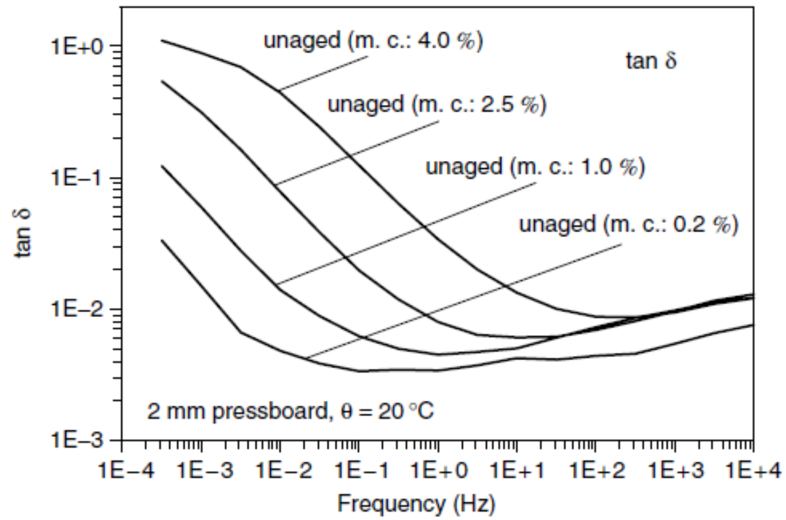


Resistive losses due to air conductivity

Discharges during a break down

DIELECTRIC SPECTROSCOPY TEST





DIELECTRIC SPECTROSCOPY THEORY

- effects of moisture over the dielectric, especially noticeable at the lower frequencies.

- Dissipation factor is a frequency dependent

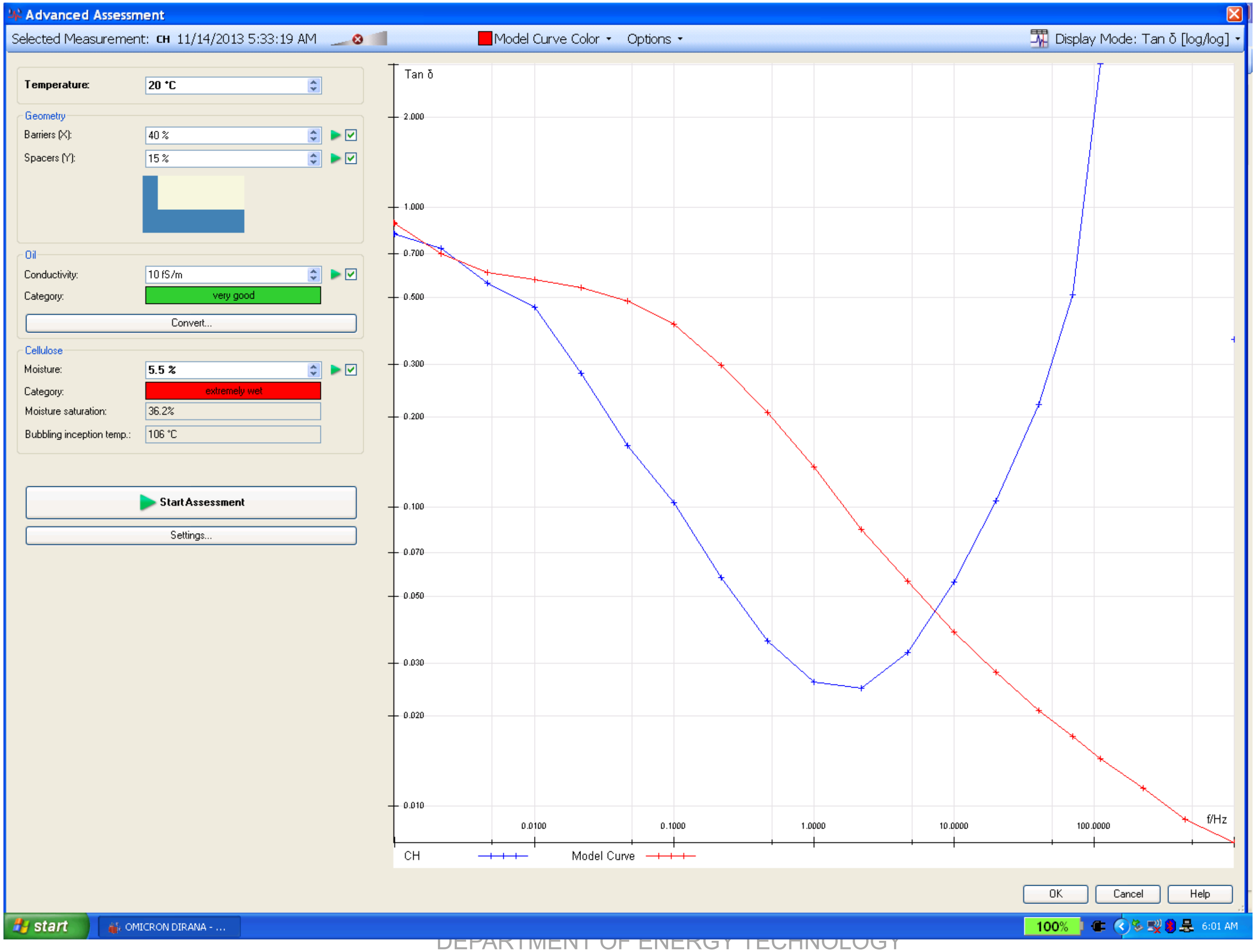
$$j(t) = \sigma_0 E(t) + \frac{dD(t)}{dt}$$

$$j(t) = \sigma_0 E(t) + \varepsilon_0 (1 + \chi(0')) \frac{dE(t)}{dt} + \varepsilon_0 \frac{d}{dt} \int_0^t f(t-\tau) E(\tau) d\tau$$

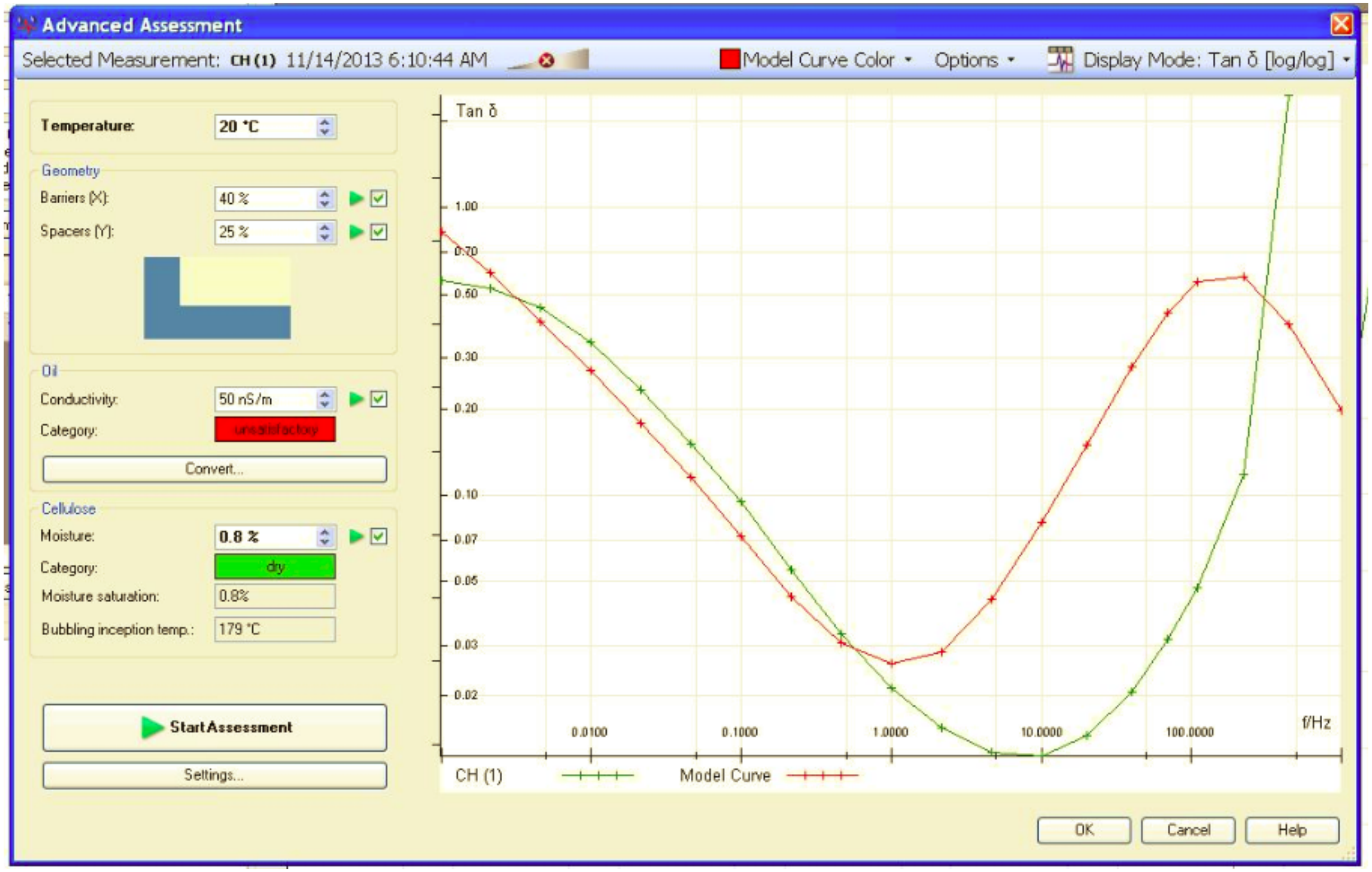
$$\Rightarrow$$

$$j(\omega) = \{\sigma_0 + \omega \varepsilon_0 \chi''(\omega) + i\omega\varepsilon_0 [1 + \chi'(\omega)]\} E(\omega)$$

DIELECTRIC SPECTROSCOPY TEST: RESULTS



DIELECTRIC SPECTROSCOPY TEST: RESULTS



CONCLUSION – LIFETIME ASSESSMENT

- Parameters and operation range:
(safety of personnel and equipment)

- System's response:
(overvoltage magnitude the line can sustain without a breakdown)

- Loss angle:
(Scheringbridge asses power quality and dielectric characteristics)

- Partial discharges:
(determine type of discharge ocurring through a graphical method)

- Dielectric spectroscopy test:
(quality, operation parameters and effects of aging of the dielectric)

- Diagnose the operation of a system and its components.

CLOSING WORDS