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# Diagnostic Measurements on Instrument Transformers

## Examples and Case Studies

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# Faults on Instrument Transformers

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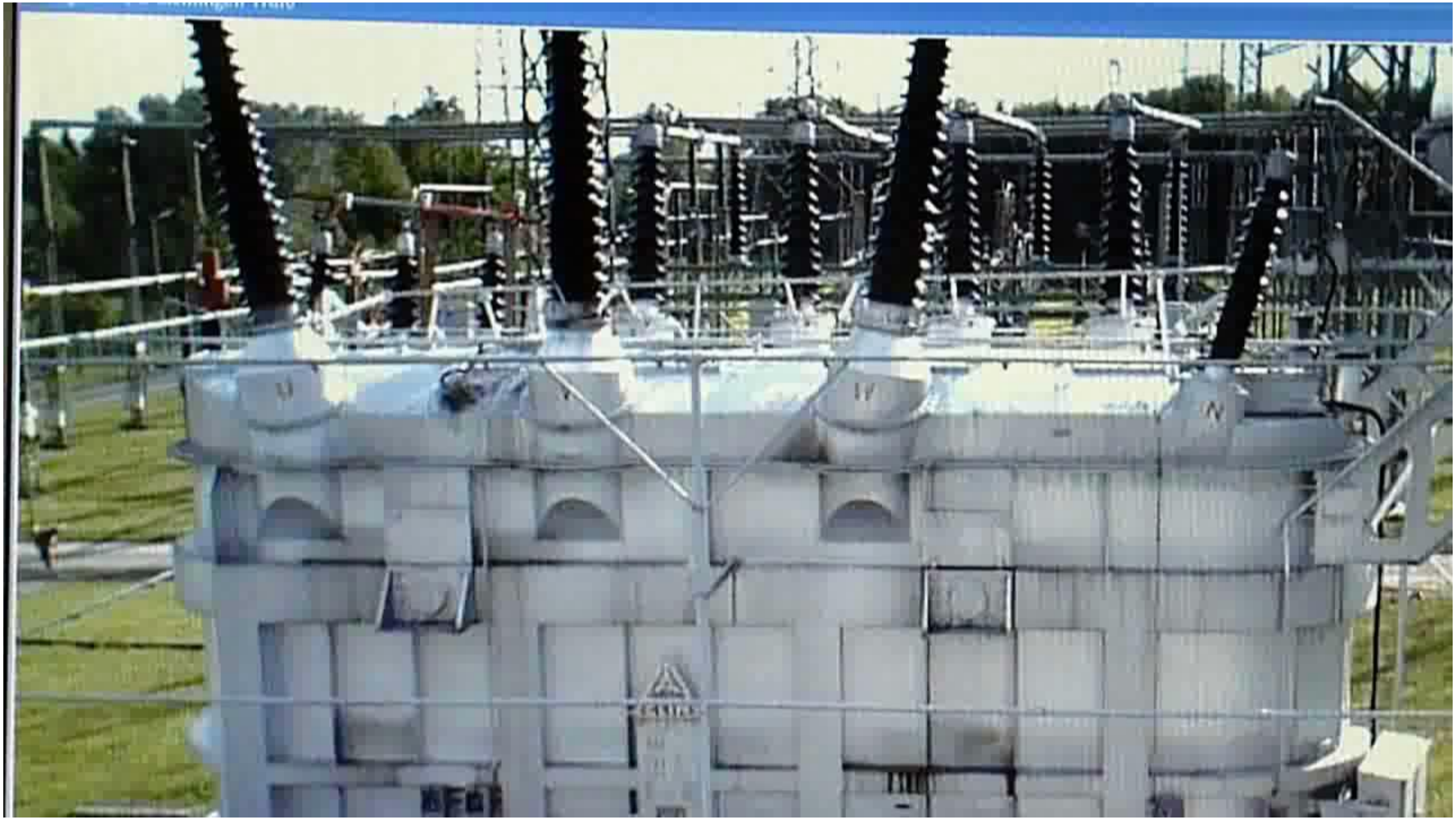

# Faults on Instrument Transformers

# Electrical Measurement Methods for Instrument Transformers

| Measurement Method | Application | Indicated by | FRT* |
|---|---|---|---|
| Oil Diagnosis (Water Content, Breakdown Voltage , DGA ...) | Routine Test | Periodical Tests e.g. every 7 years | FRT |
| Tan-Delta / PF | Insulation Diagnosis, Ageing, Moisture | Karl-Fischer Titration, DGA | FRT |
| Dielectric Response | Insulation Diagnosis, Ageing, Moisture | Karl-Fischer Titration, DGA | FRT |
| Partial Discharge Measurement | Diagnosis of the Insulation, Partial Discharges | DGA | T |
| Ratio VT / CVT | Accuracy | After Outage, Oil Values | FRT |
| Ratio CT | Accuracy | Wrong Current Readings | FRT |
| Excitation Current VT | Core Faults, Shorted Turns | After Outage, Oil Values | FT |
| Excitation Current CT | Knee Point Voltage | Malfunction of the Protection | FRT |

*F=Fingerprint, R=Routine, T=Troubleshooting

# Diagnostic Measurements on Instrument Transformers – Examples and Case Studies

- **Insulation Diagnosis with Dielectric Response Measurements**
- Partial Discharge Measurements

# Insulation in a Current Transformer

# Insulation in a Voltage Transformer

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# Determination of the Water Content in the Cellulose of Instrument Transformers with Dielectric Response Measurements

- Insulation of instrument transformers is different from power transformers:
  - No oil ducts
  - High content of paper in the oil-paper insulation

  → different settings of the geometry is necessary!

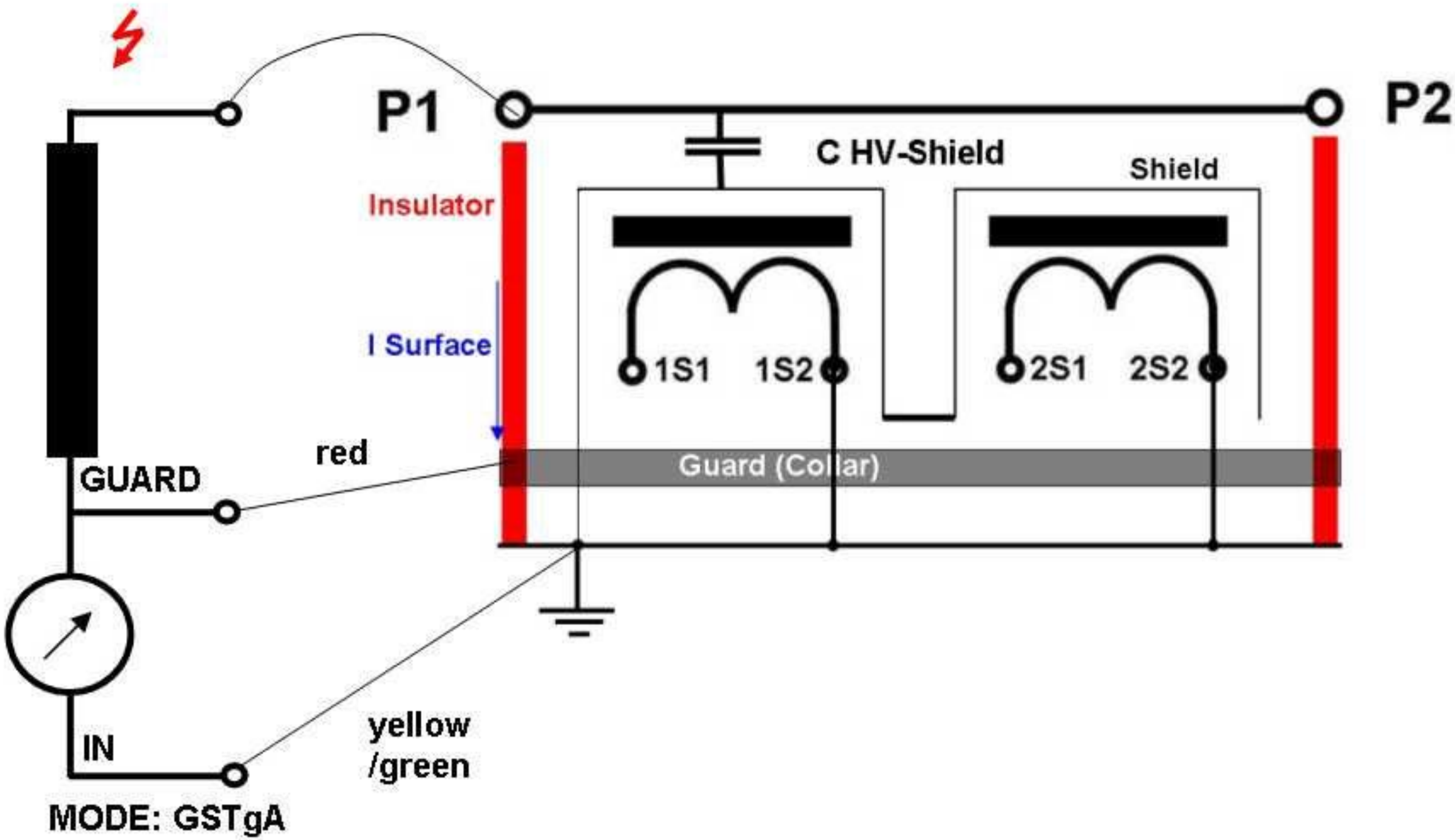
<u>Power Transformer:</u>

- Barriers: 15 % - 45 %
- Spacers: 14 % - 25 %

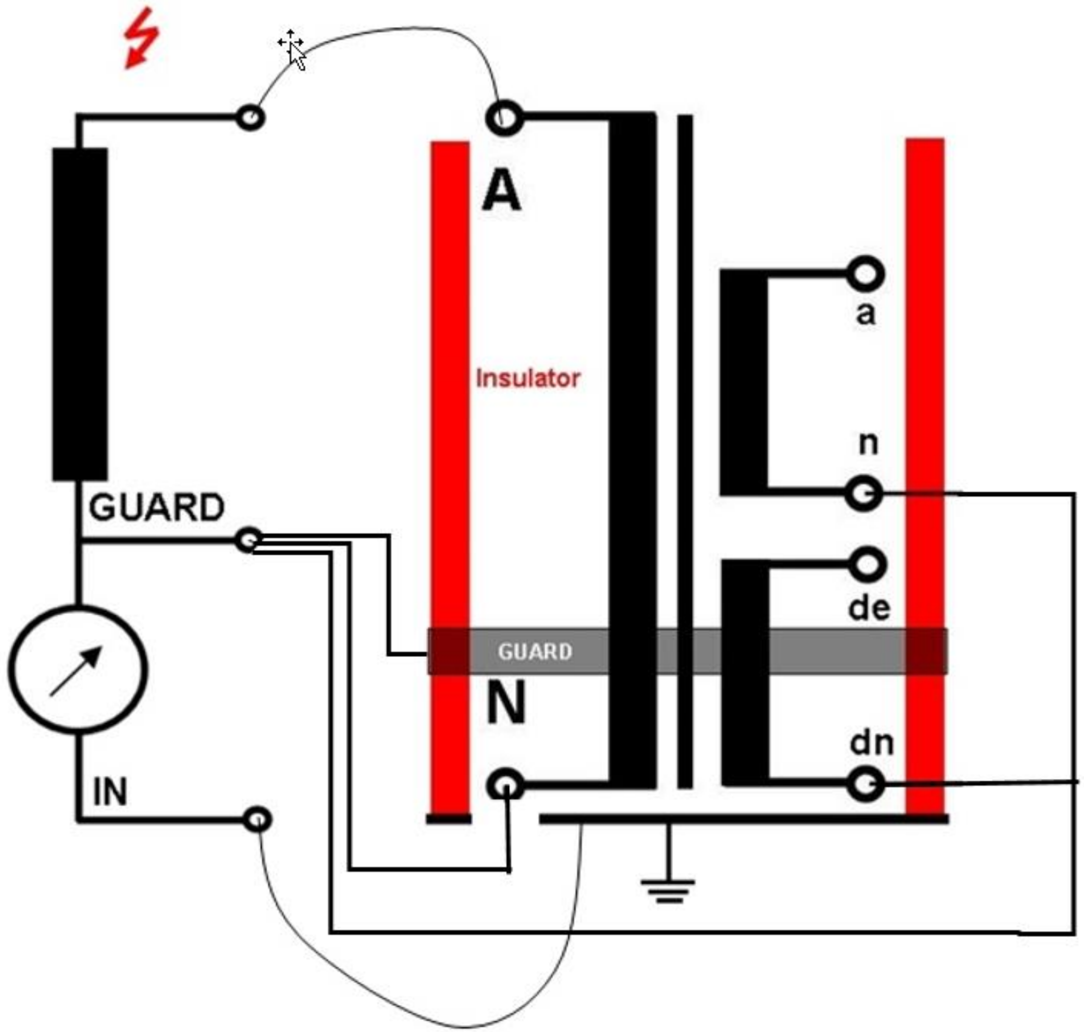
<u>Instrument Transformer:</u>

- Barriers: 70 % - 100 %
- Spacers: 15 % - 50 %

# Measurement Current Transformer



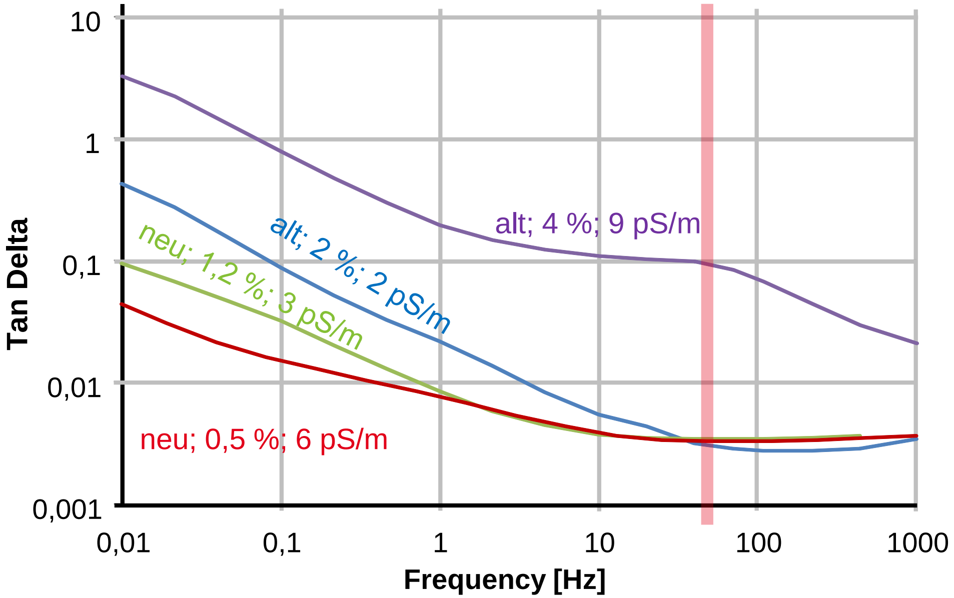
# Measurement Voltage Transformers

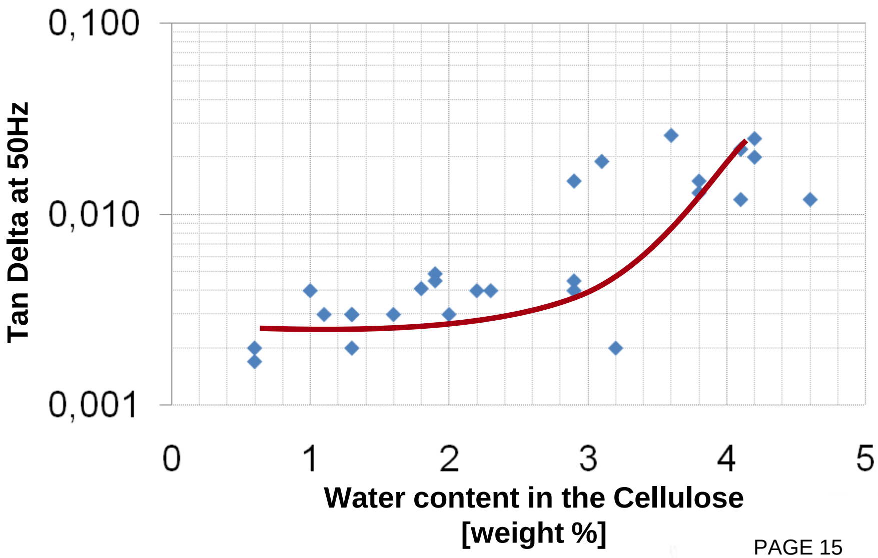


# Tan Delta at Power Frequency

- tan(δ) at power frequency is only indicating highly aged insulation respectively high water contents
- tan(δ) is dependent on the temperature

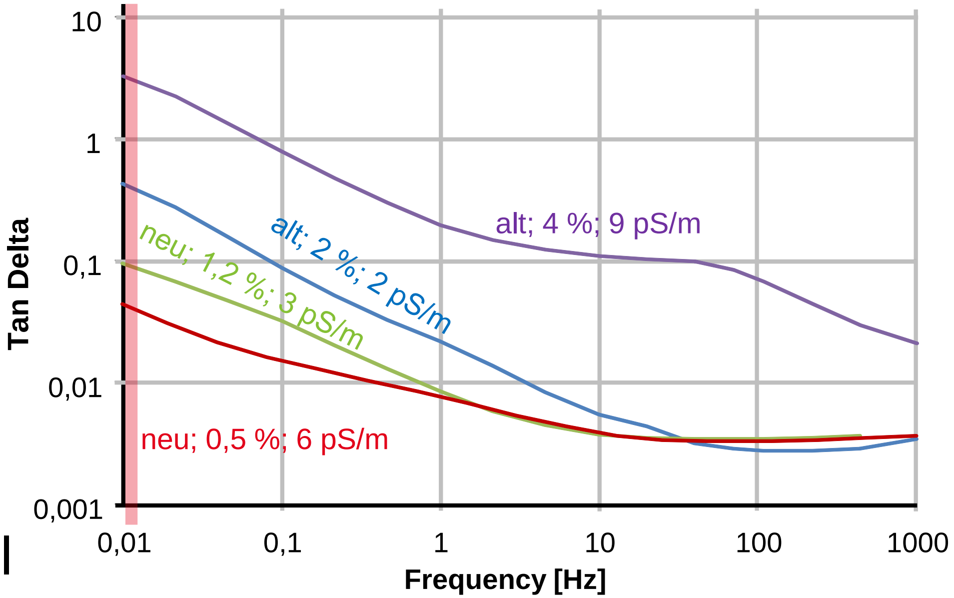
➢ tan(δ) at power frequency is not an effective tool for the assessment of the insulation



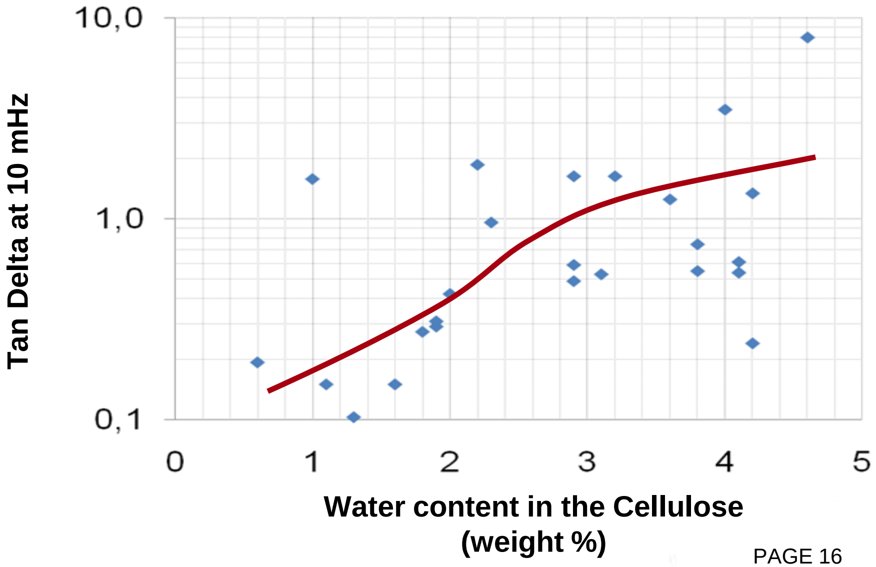



# Tan Delta at 10 mHz

- tan(δ) at 10 mHz is strongly dependent on ageing and moisture
- tan(δ) is dependent on the temperature




➢ tan(δ) at 10 mHz is a good tool for the insulation assessment

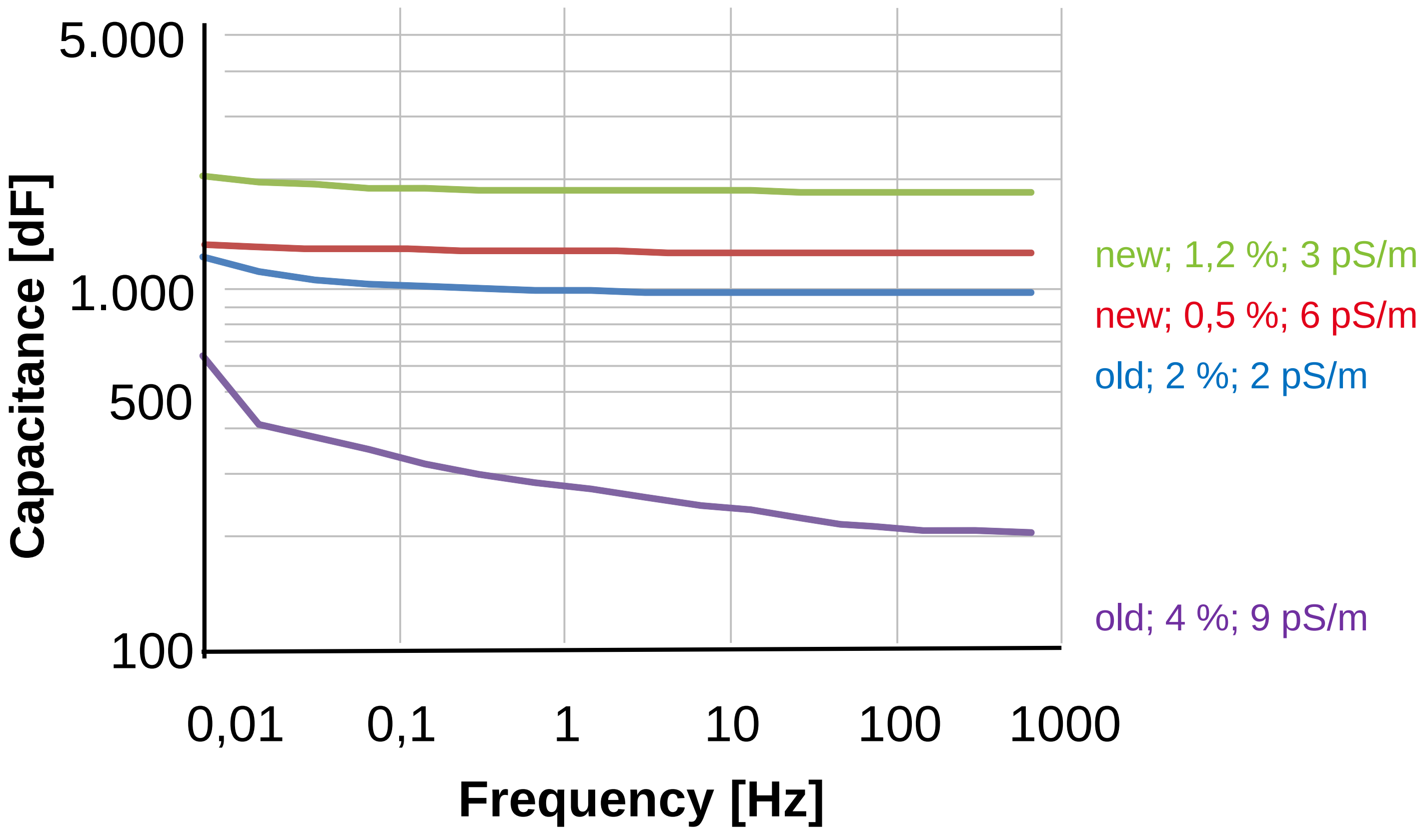



<u>Drawback:</u>

Dependency on the temperature

# Capacitance over Frequency

Capacitance is constant for dry instrument transformers, for wet IT's it is increased at lower frequencies

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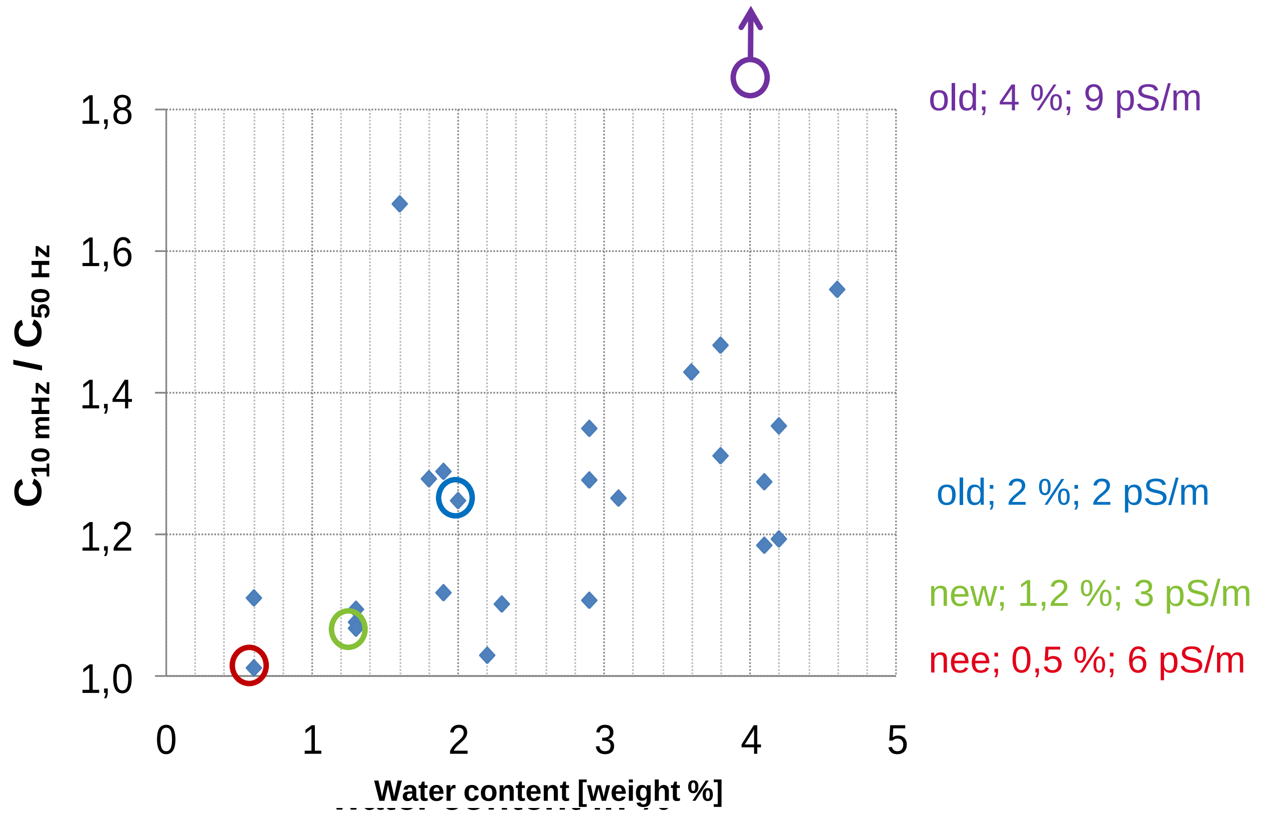
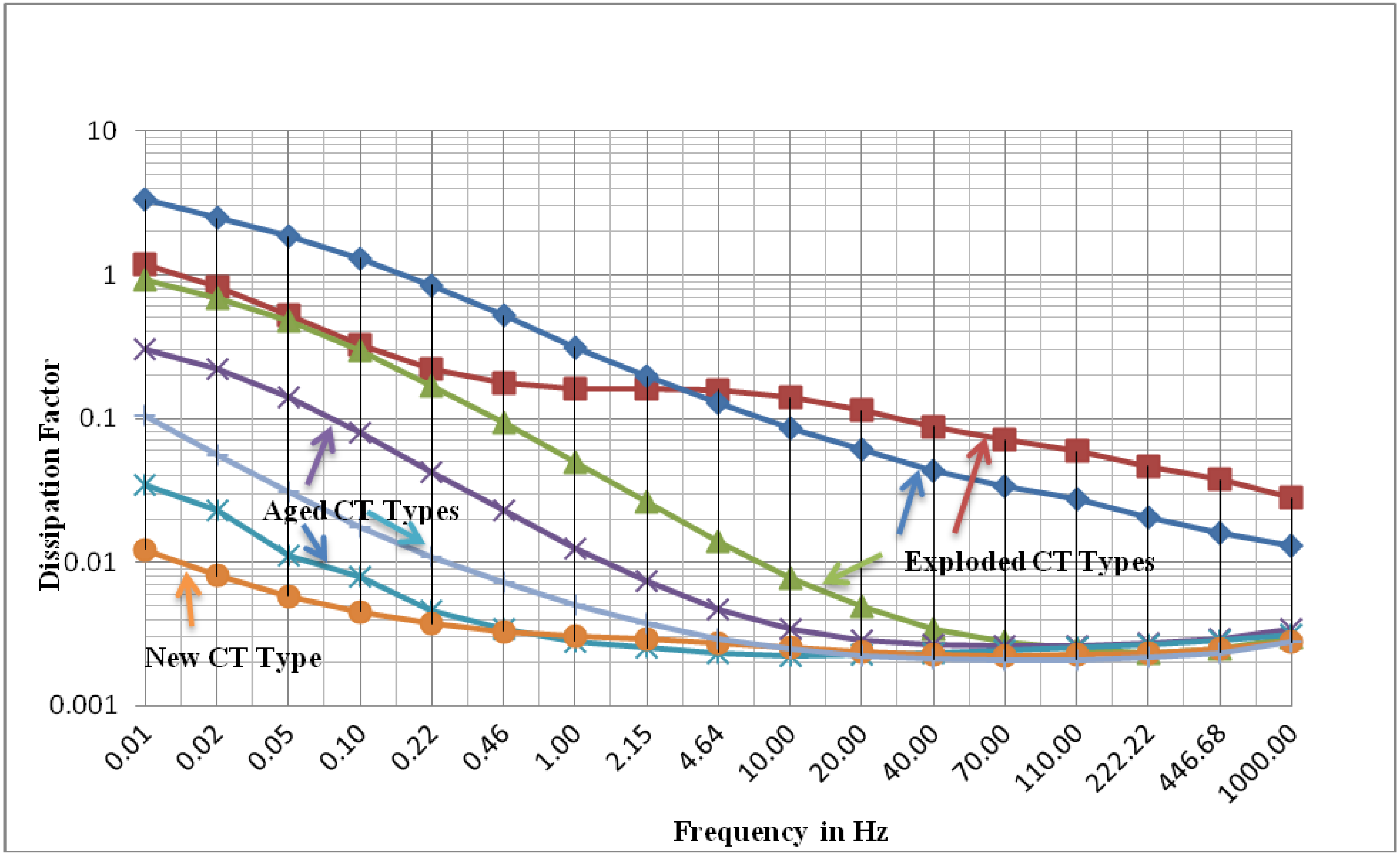
# Capacitance over Frequency

- Capacitance is constant for dry IT‘s, for wet IT‘s not
- $C_{10mHz}/C_{50Hz}$ is independent on the temperature



# Tan Delta Curves of different CTs



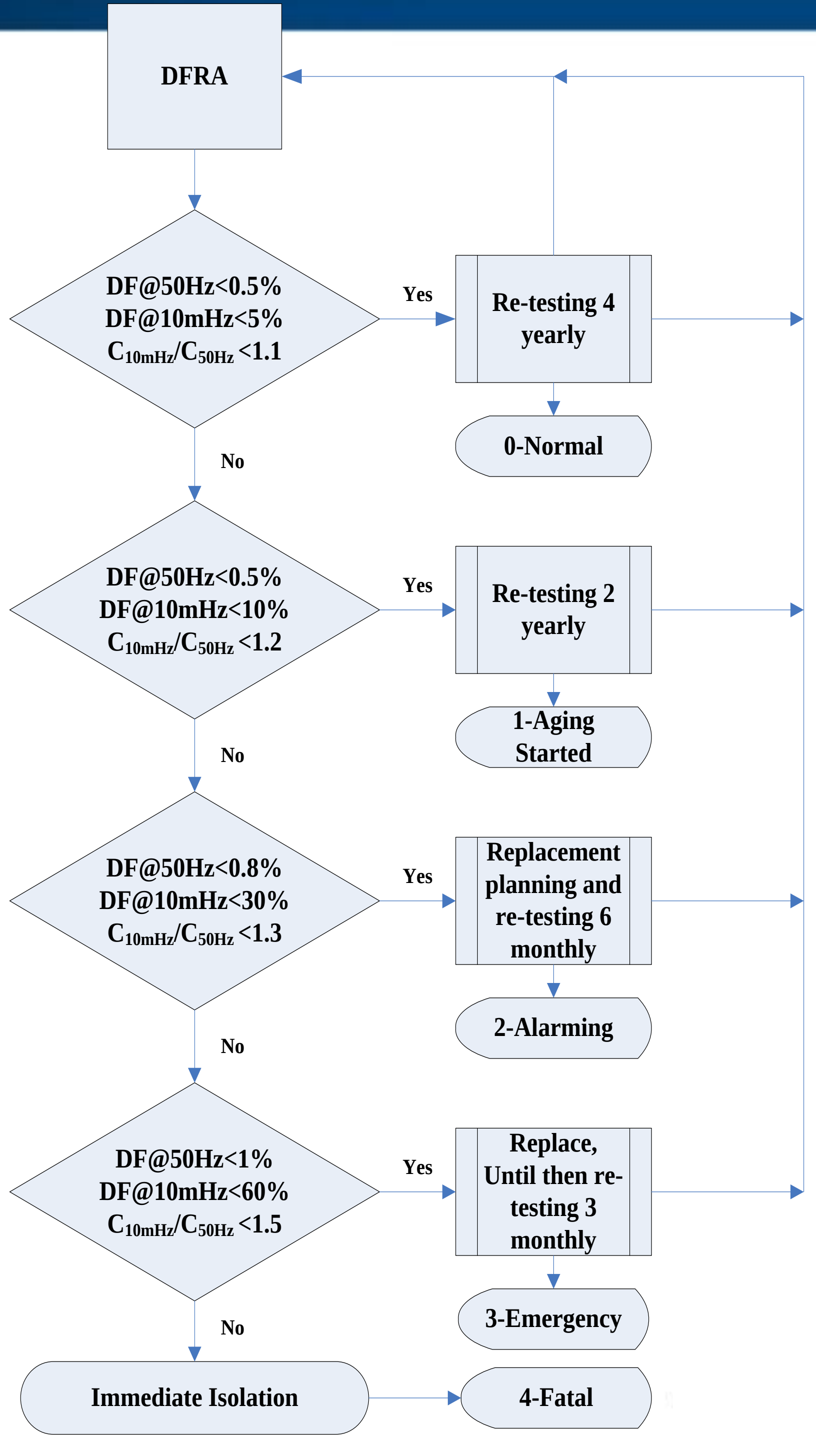

Source: Pradeep Nandasena, CEPED Kuala Lumpur 2015

# Capacitance Ratio

| CT Group | Average Ratio of Capacitance at 10mHz to Capacitance at 50Hz |
| --- | --- |
| New CTs | 1.02 |
| New CTs | 1.05 |
| Aged CTs | 1.05 |
| Sister CTs<br>of failed CT type | 2.28 |

Source: Pradeep Nandasena, CEPED Kuala Lumpur 2015

# Decision Tree




Source: Pradeep Nandasena, CEPED Kuala Lumpur 2015

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# Diagnostic Measurements on Instrument Transformers – Examples and Case Studies

- Insulation Diagnosis with Dielectric Response Measurements
- **Partial Discharge Measurements**

# HV Transformer with Coupling Capacitor, Quadripole and PD Instrument

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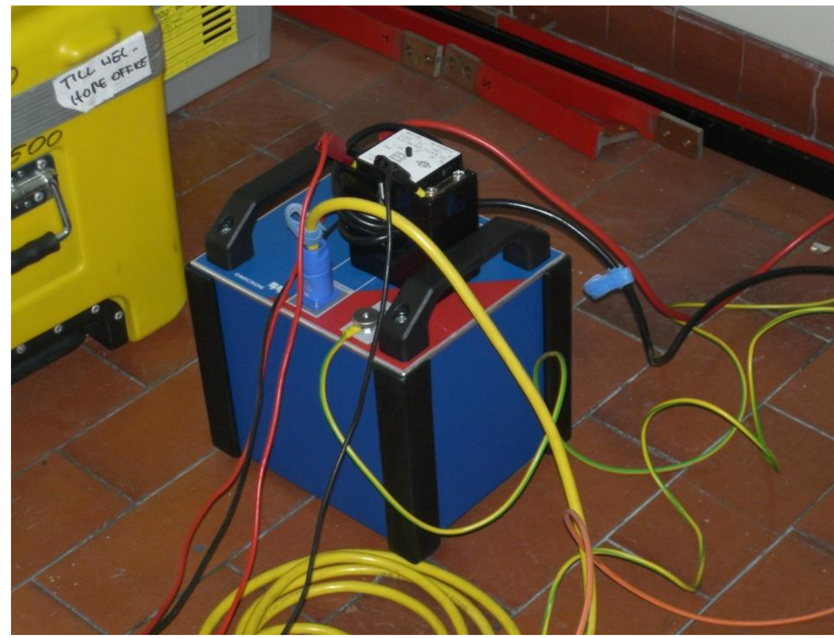
# Generation of the 150Hz Test Voltage with CPC100 + TR7

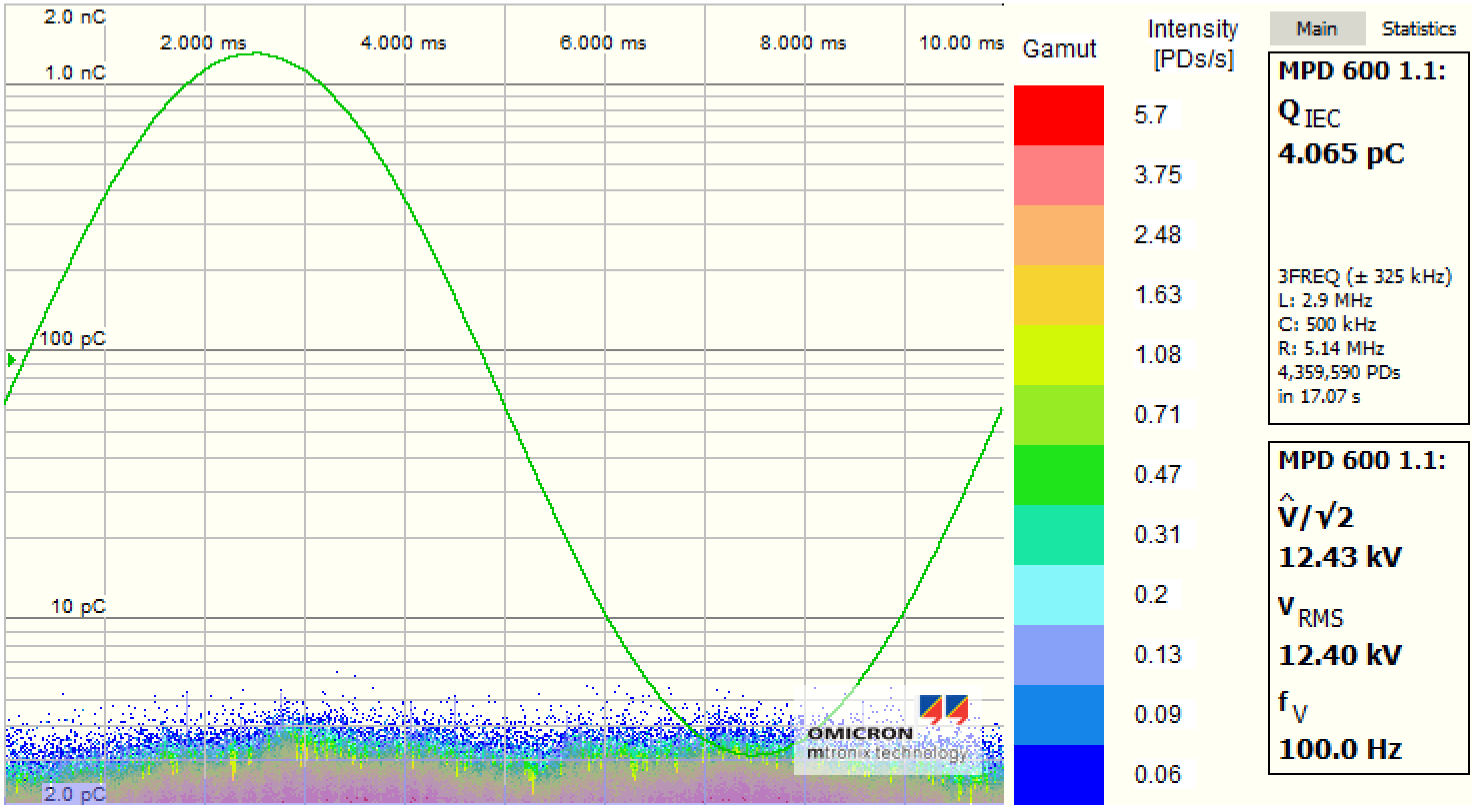



# PD Measurement on 10kV Instrument Transformers

VT

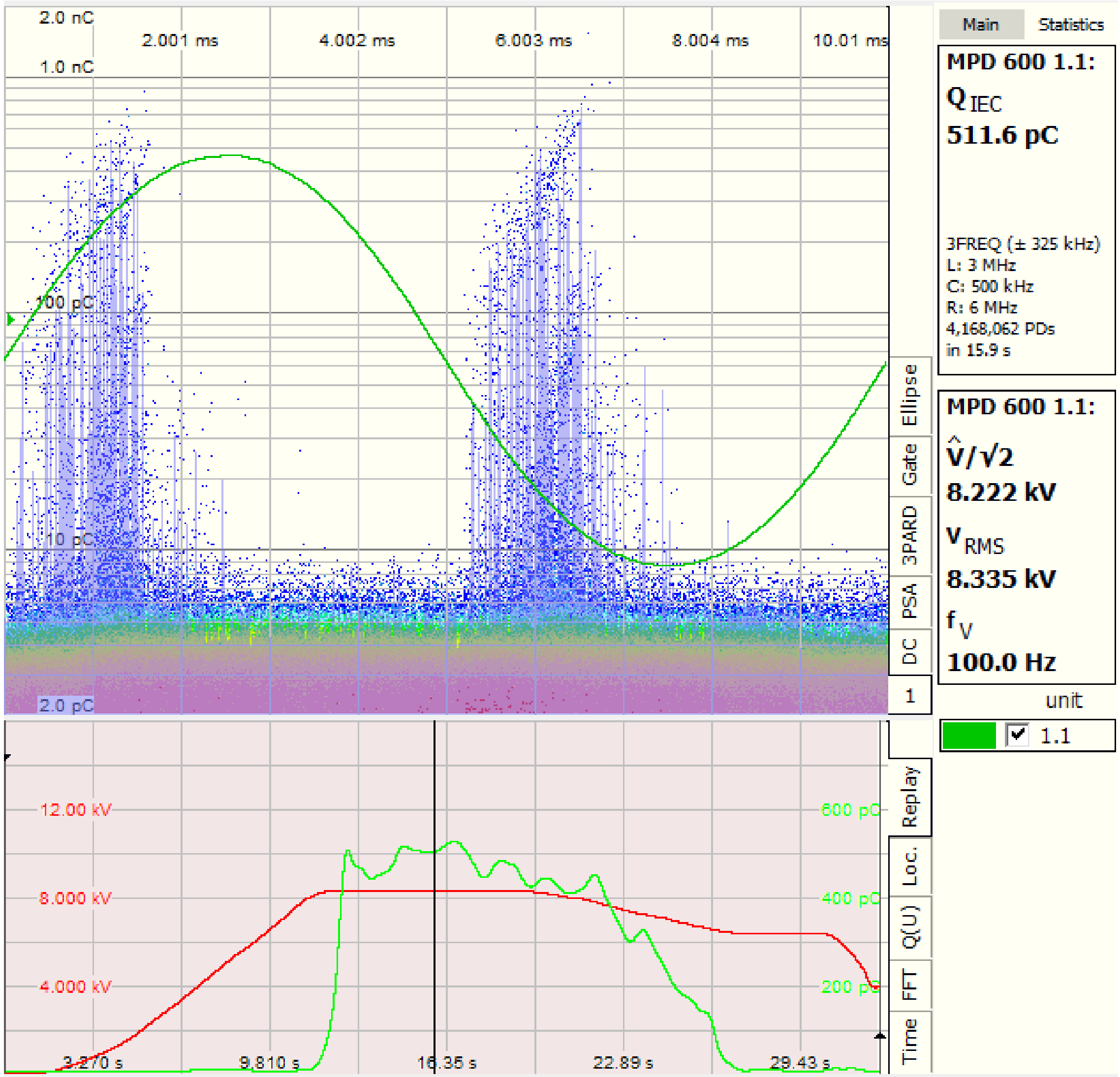
CT's

# Good CT with PD < 10pC at 12kV



# PD on a Voltage Transformer

## PD > 500pC at 8kV

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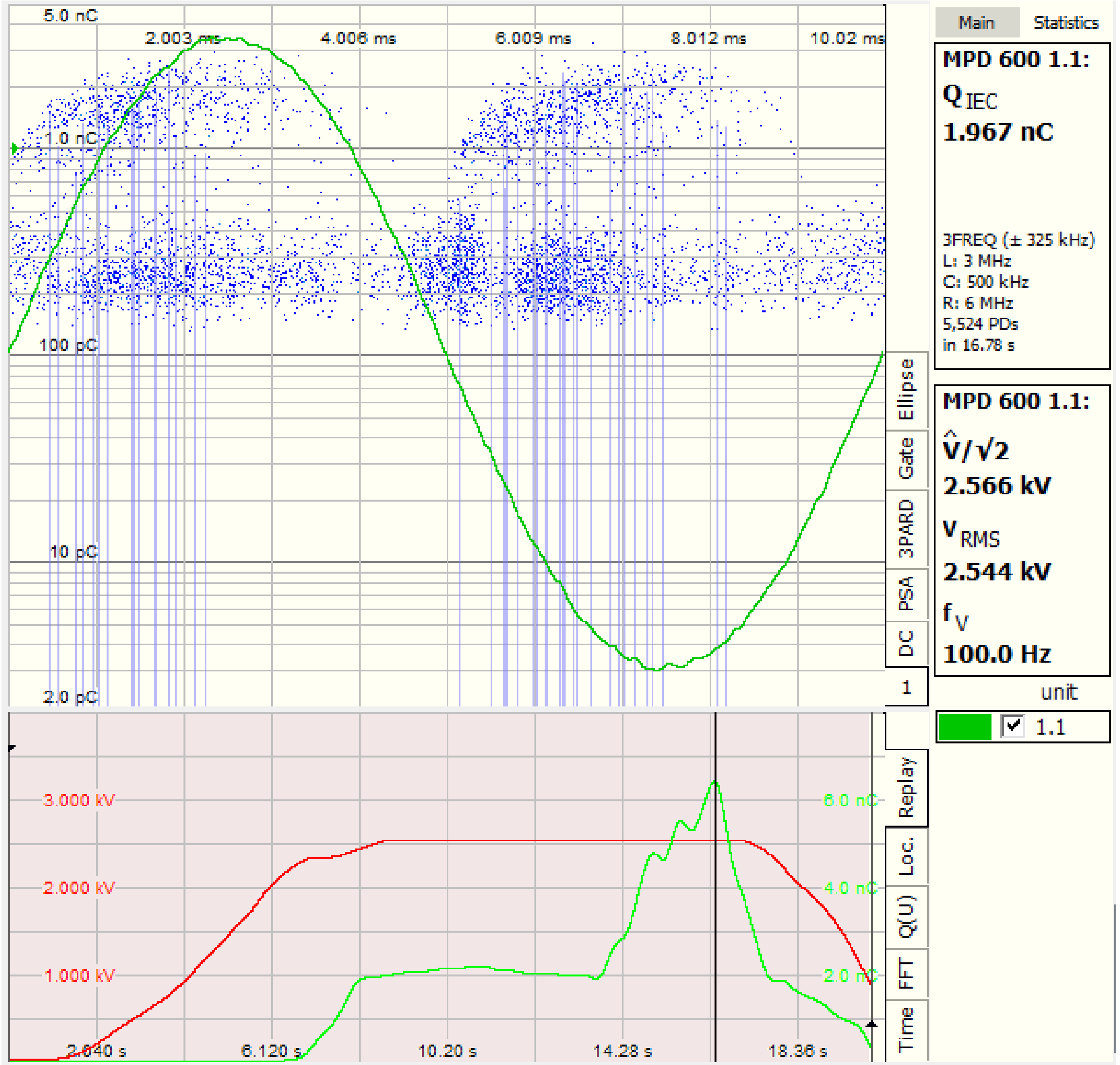
# PD on a Voltage Transformer

## TE = 2nC at 2.5kV!

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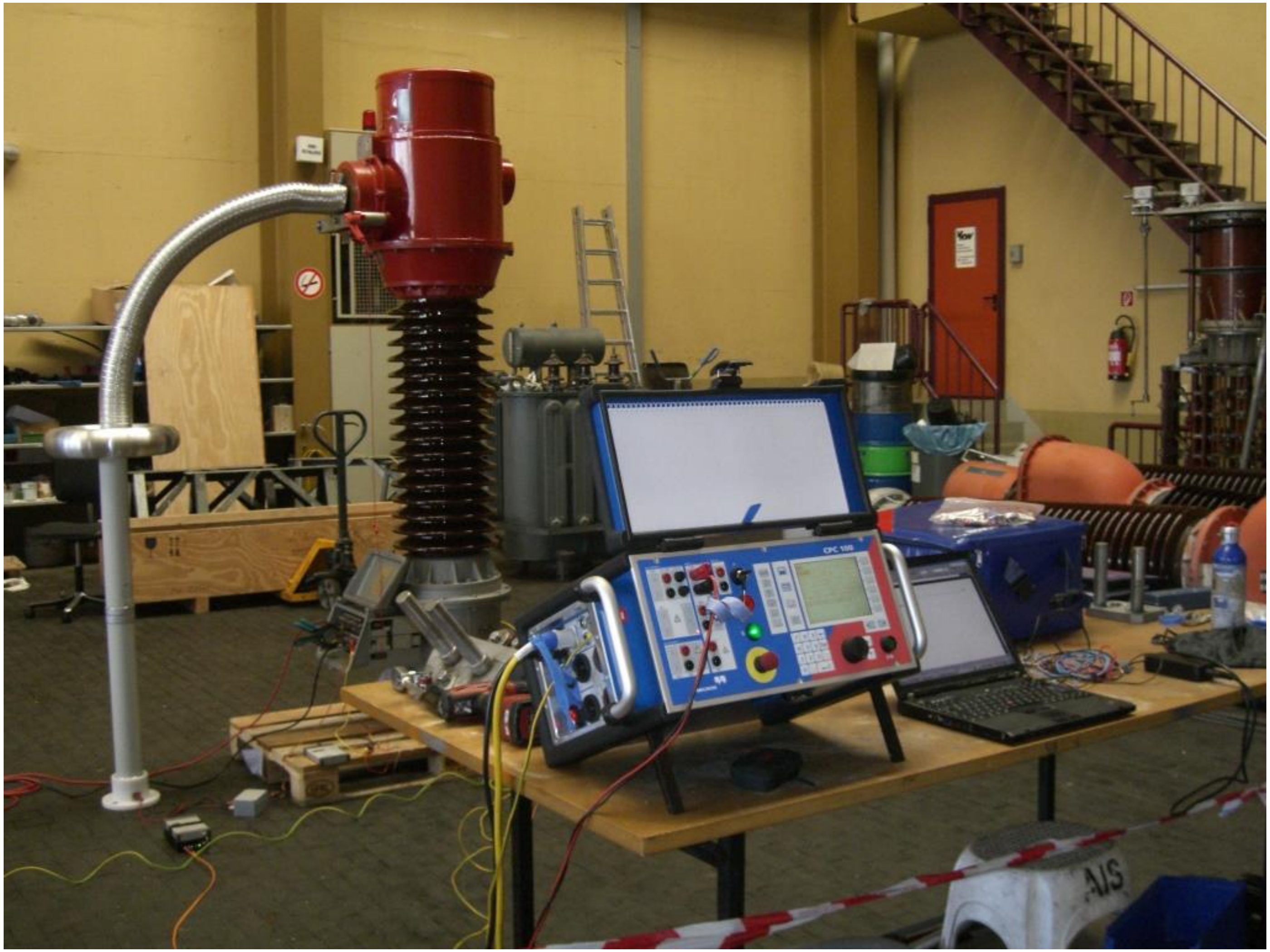
# PD Measurement on 24kV Voltage Transformers ( ≈ 30 years old)

# PD Measurement on 24kV Voltage Transformers ( ≈ 30 years old)

| 24kV Voltage Transformers pC | | | | Limits acc. to IEC 60689 | | |
|---|---|---|---|---|---|---|
| VT's | 30kV | 24kV | 16kV | Test Voltage | kV | pC |
| 1 | 130 | <1 | <1 | Um = 24kV | 24kV | 50 |
| **2** | **240** | **150** | **60** | 1,2 x Um/Sqrt(3) | 16kV | 20 |
| **3** | **600** | **330** | **42** | | | |
| 4 | 126 | <1 | <1 | | | |
| **5** | **242** | **236** | **78** | | | |
| 6 | <1 | <1 | <1 | | | |
| **7** | **181** | **164** | **51** | | | |

# High $H_2$ and $C_2H_2$ Values on a 123kV IT



# High $H_2$ and $C_2H_2$ Values on a 123kV IT

| H2 | CO | CO2 | CH4 | C2H2 | C2H4 | C2H6 |
|---|---|---|---|---|---|---|
| 264 | 113 | 660 | 39 | 133 | 27 | 21 |

| $H_2$ | CO | $CO_2$ | $CH_4$ | $C_2H_6$ | $C_2H_4$ | $C_2H_2$ |
|---|---|---|---|---|---|---|
| 300 | 300 | 900 | 30 | 50 | 10 | 2 |

limits for sealed instrument transformers – IEC 60599

# High $H_2$ and $C_2H_2$ Values on a 123kV IT

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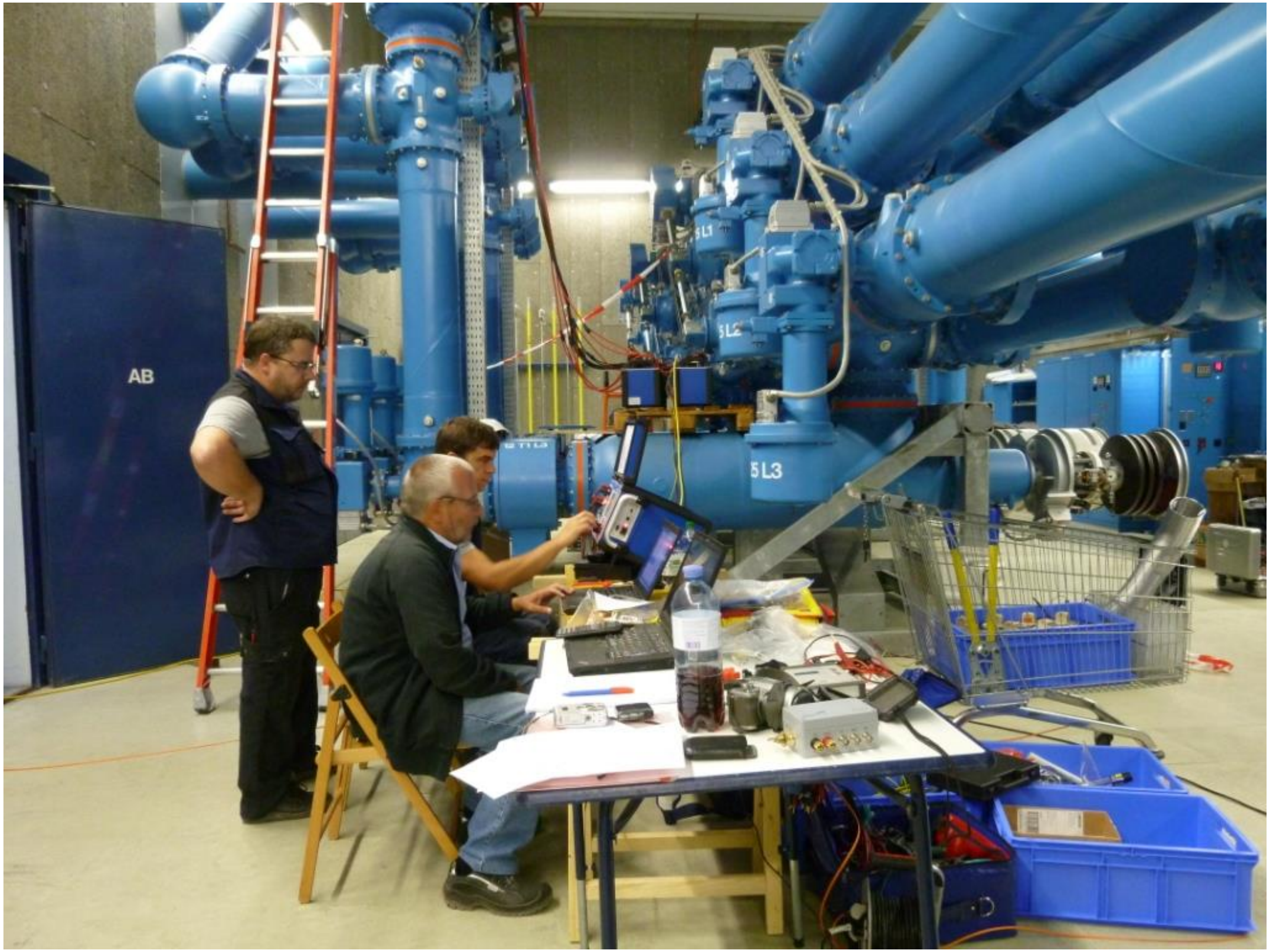
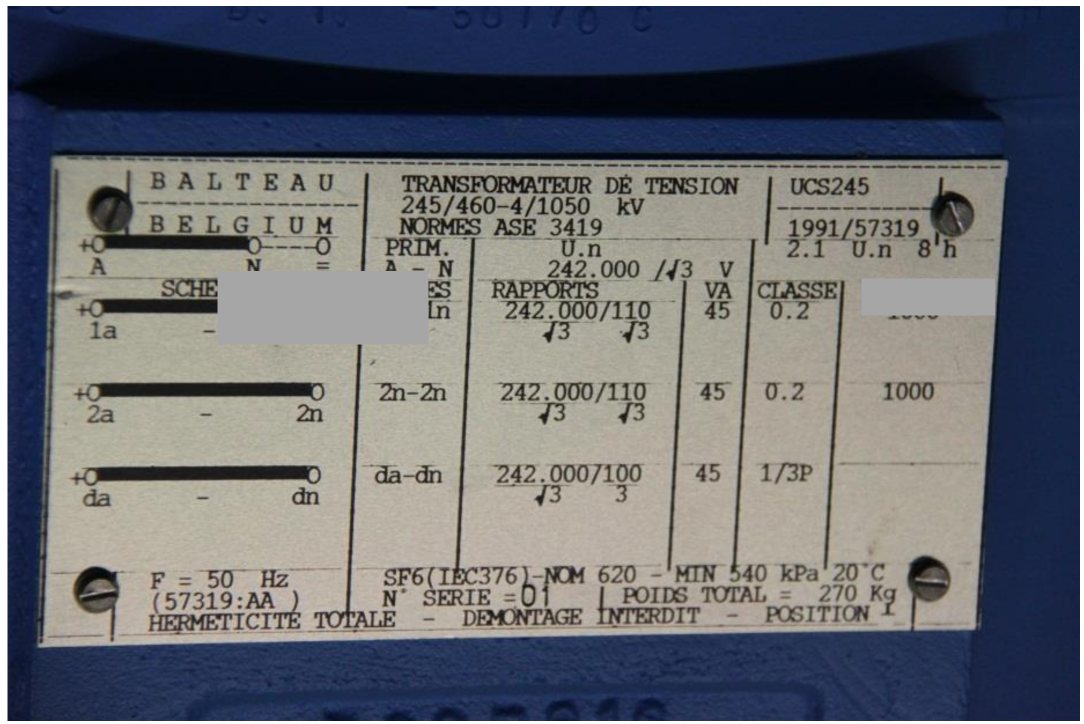
# PD Measurements on GIS Voltage Transformers



# Technical Assessment

**Test Voltage: 1.2 x Um / √3 = 1.2 x 242 / √3  =  170 kV**

# Technical Assessment

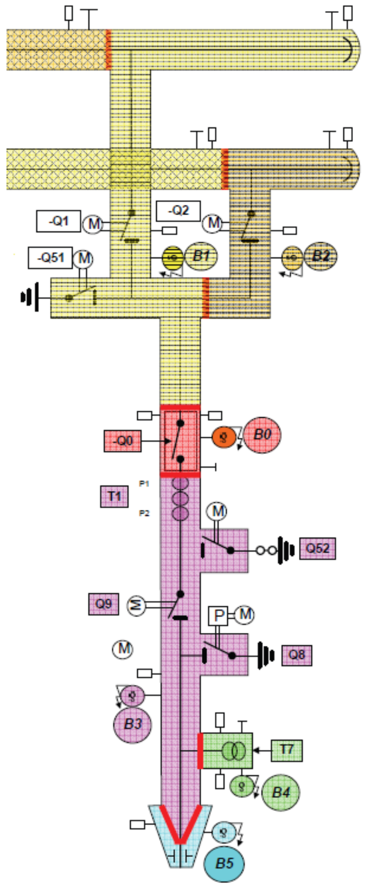
## Calculation of the test current

| Voltage Transformer Data | | |
|---|---|---|
| Primary voltage | $U_{Prim}$ | 242 [kV] |
| Sekundary voltage | $U_{Sec}$ | 0,11 [kV] |
| Maximum operation voltage | $U_m$ | 245 [kV] |
| Operation voltage | U | 230 [kV] |

| Calculation of the Capacitances | | |
|---|---|---|
| Capacitance of the busbar -B3 | $C_{GIS}$ | 600 [pF] |
| Capacitance of the voltage transformer | $C_{TP}$ | 300 [pF] |
| Capacitance of the HV SF6 - outdoor bushing | $C_{Trav}$ | 400 [pF] |
| Cpacitance of the coupling capacitor 300 kV | $C_{Condo}$ | 300 [pF] |
| Total capacitance | $C_{tot}$ | 1600 [pF] |

| Test Data | | |
|---|---|---|
| Test voltage | 1.2 * Um / V3 | 170 [kV] |
| Test frequency | f | 60 [Hz] |

| Calculation of the Test Current | | |
|---|---|---|
| Primary current (245kV) | $I_{Prim}$ | 0,103 [A] |
| Secondary current (110V) | $I_{Sec}$ | **226** [A] |
| Needed test power = 75V * 226A | S | **17** [kVA] |

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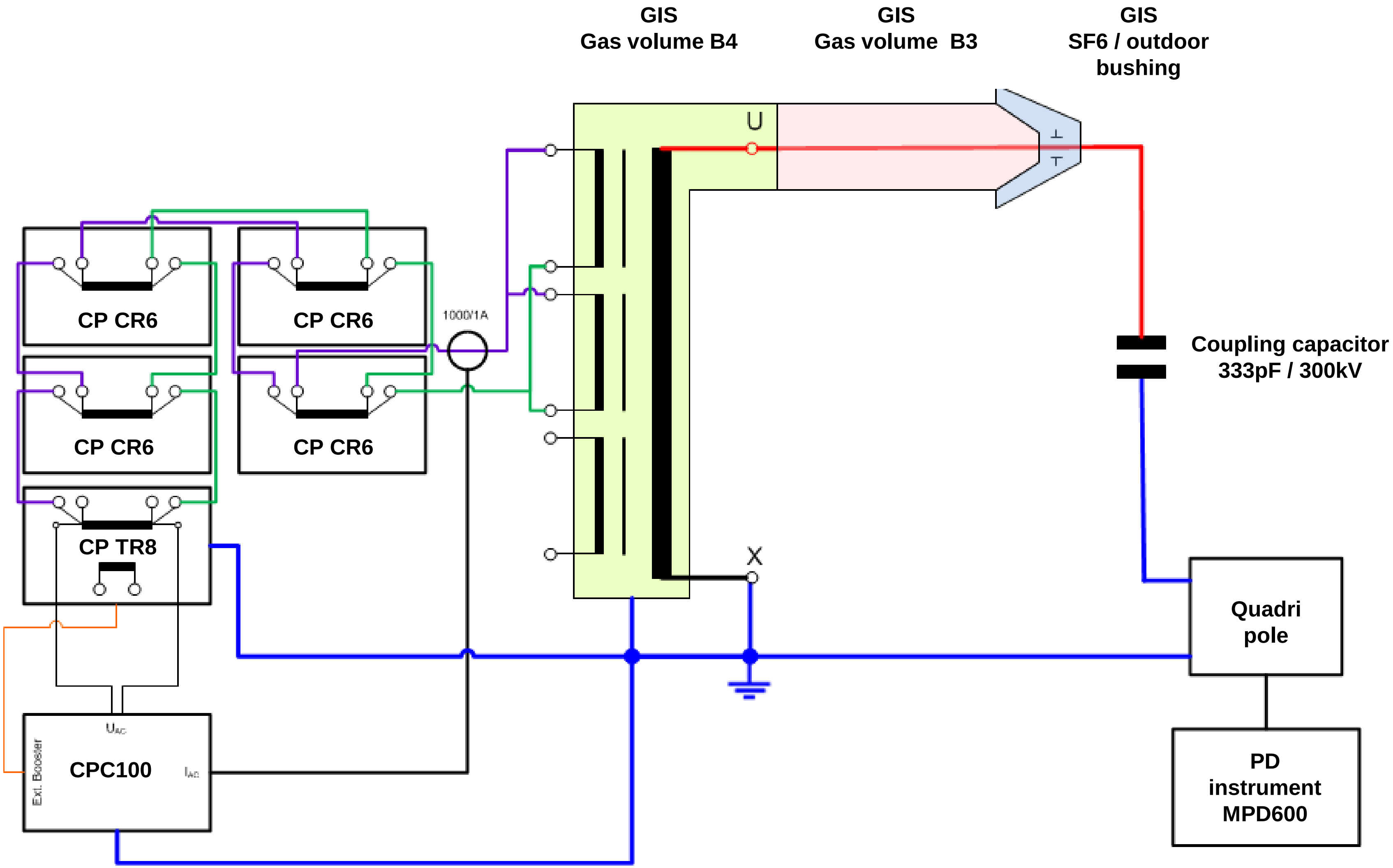
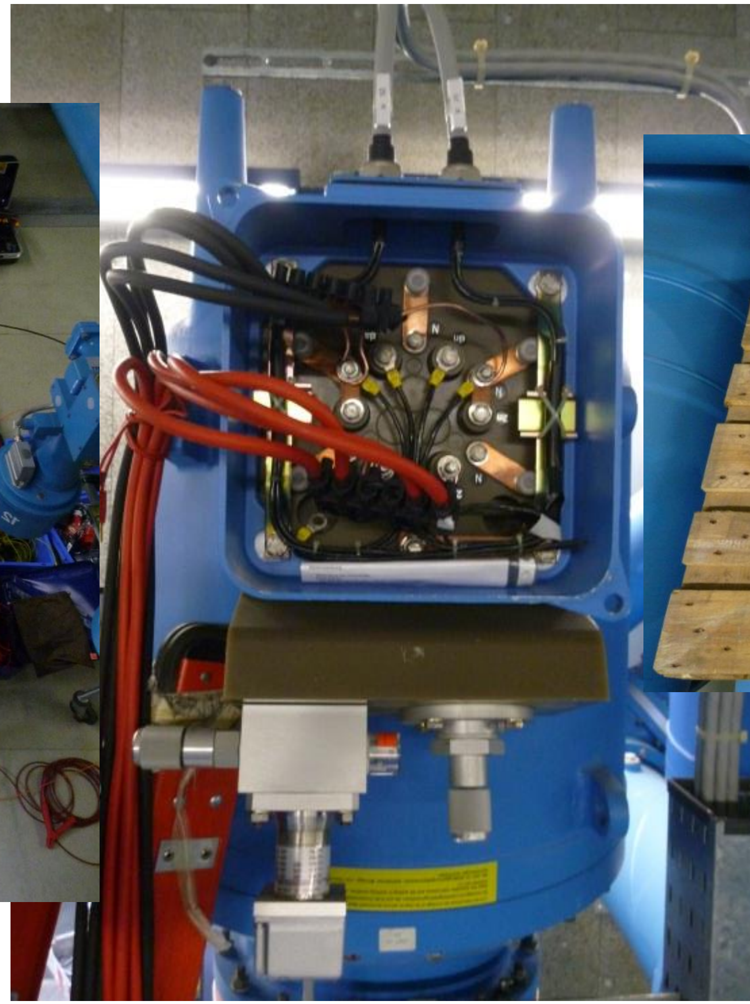
# Test Setup

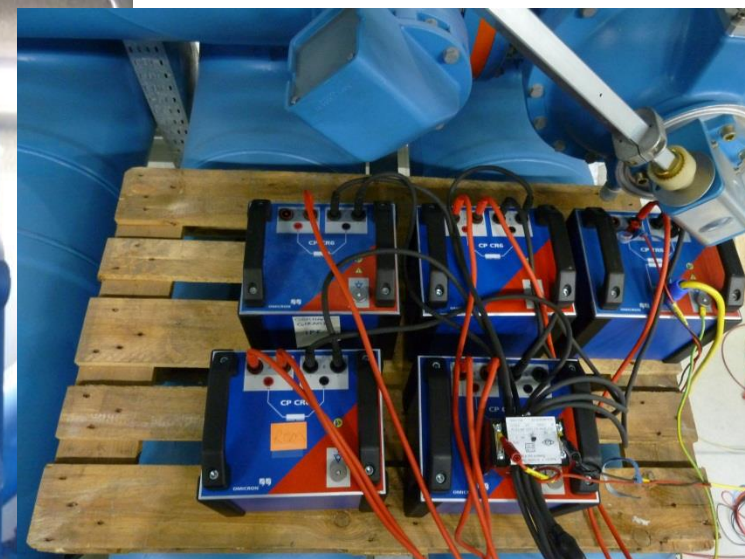


GIS
Gas volume B4
GIS
Gas volume B3
GIS
SF6 / outdoor
bushing
U
CP CR6
CP CR6
CP CR6
CP CR6
1000/1A
CP TR8
X
Coupling capacitor
333pF / 300kV
Quadri
pole
PD
instrument
MPD600
CPC100
Ext. Booster

# Setup - 110V Side



CPC100 (Source)



Matching transformer and compensation reactors

Secondary terminals

# Setup
# 242kV Side

**Coupling Caoacitor**
**333pF 300kV**
**with Quadripole**
**and MDD600**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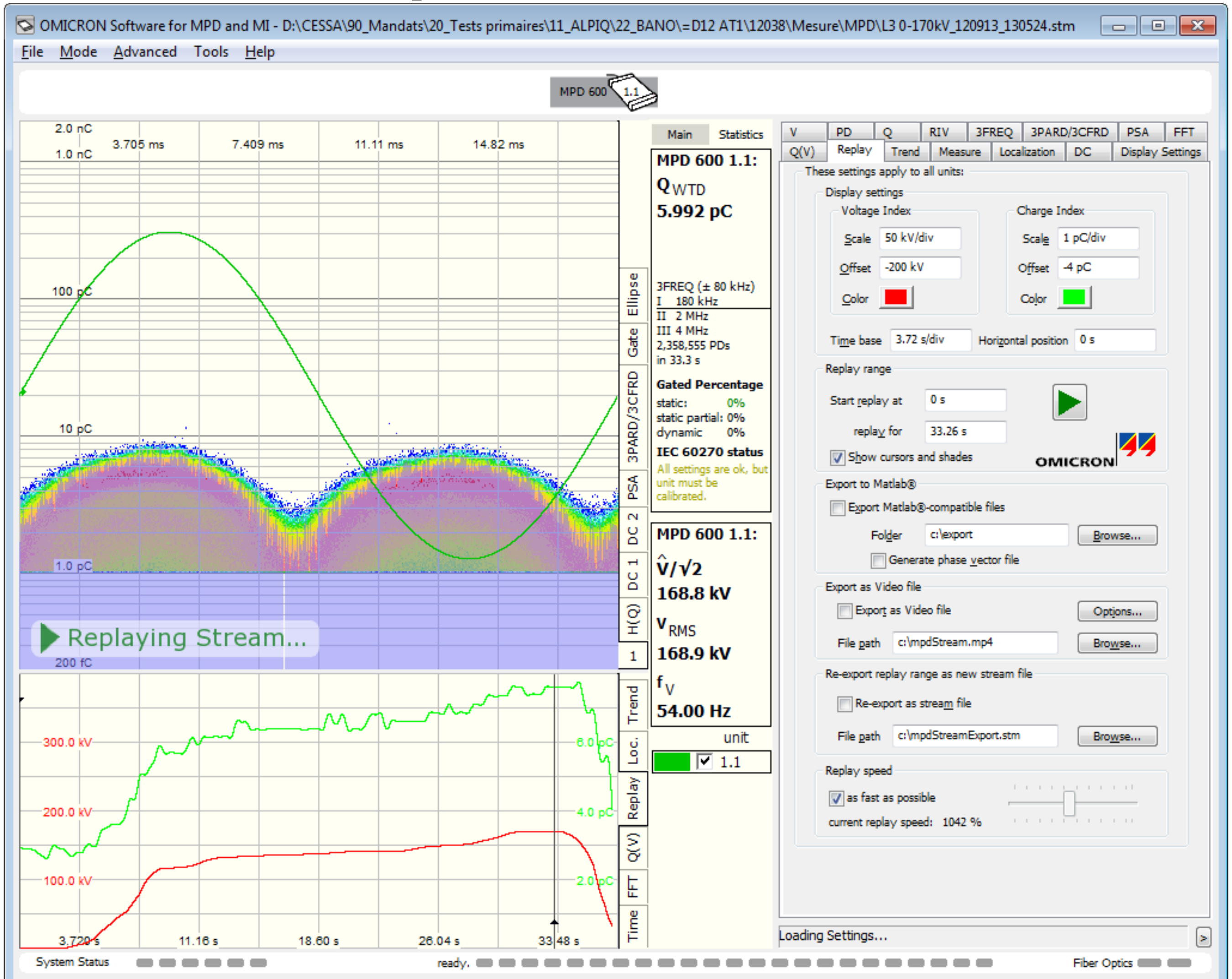
# PD Level < 6pC at 170kV

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## Questions and Remarks?

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