TRANSFORMERS MAGAZINE'S
INDUSTRY NAVIGATOR

SUSTAINABILITY AND DIGITALIZATION

Condition Monitoring of Power Transformer Insulation: HV Bushings, Partial Discharges and Transient Overvoltages

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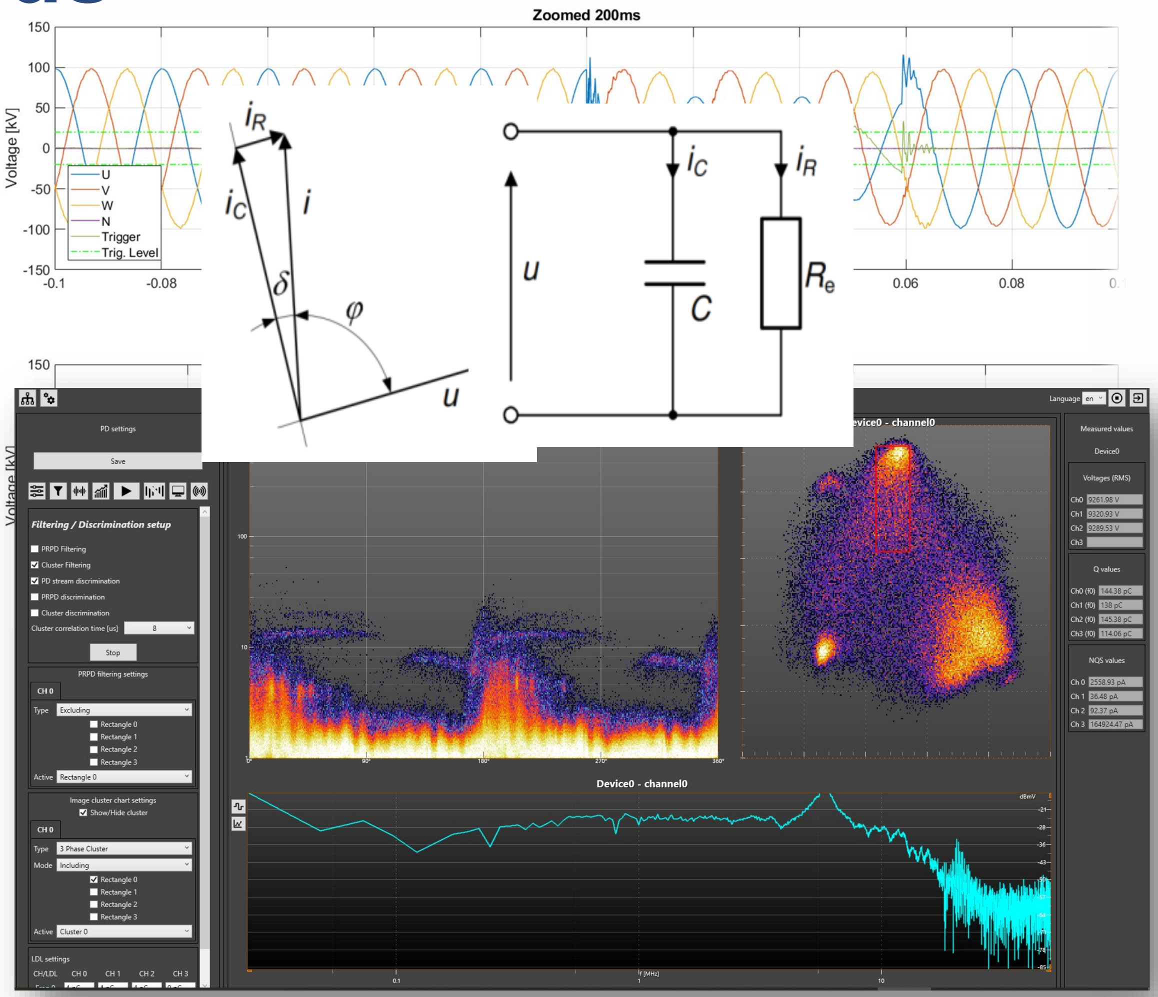
Purpose of Condition monitoring

- To detect emerging faults
- To enable condition-based maintenance
- To provide optimum transformer management
- To improve personnel and environment safety
- To enhance fault cause analysis

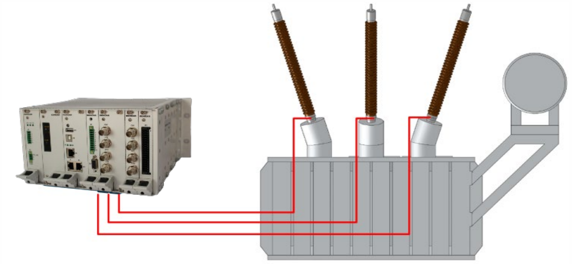
Insulation Monitoring Methods

- Bushing Monitoring
  - Capacitance C1
  - Dissipation Factor
- Transients Overvoltage Monitoring
  - Estimation of insulation stress
  - Grid modelling
- Partial Discharges Measurements and Monitoring
  - Apparent Charge
  - PRPD map used for pinpointing the cause
  - Localization of PD source

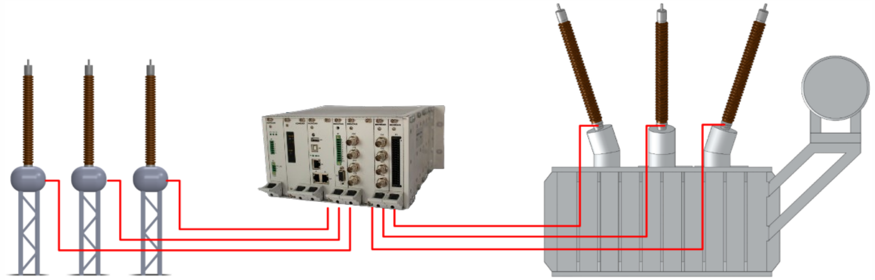


Bushing Monitoring methods

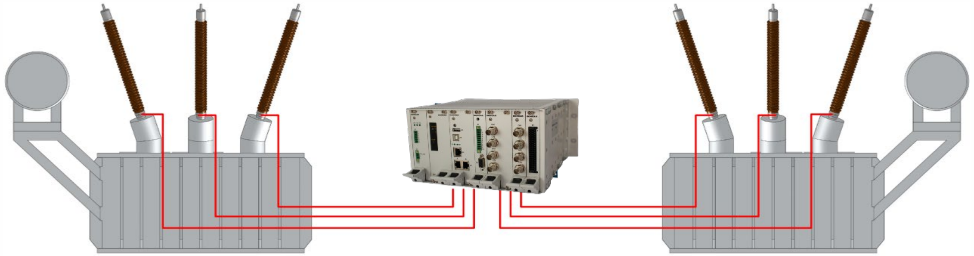
- 3phase bank methods
    - Sum of currents
    - Adjacent Phase to Phase
    - Advantages:
        - Simple method
        - Less cabling
        - High sensitivity
    - Disadvantages:
        - Network unbalance problems



- VT reference method
    - Advantages:
        - Absolute measurement
        - No network unbalance problems
        - Faster response
    - Disadvantages:
        - More cabling

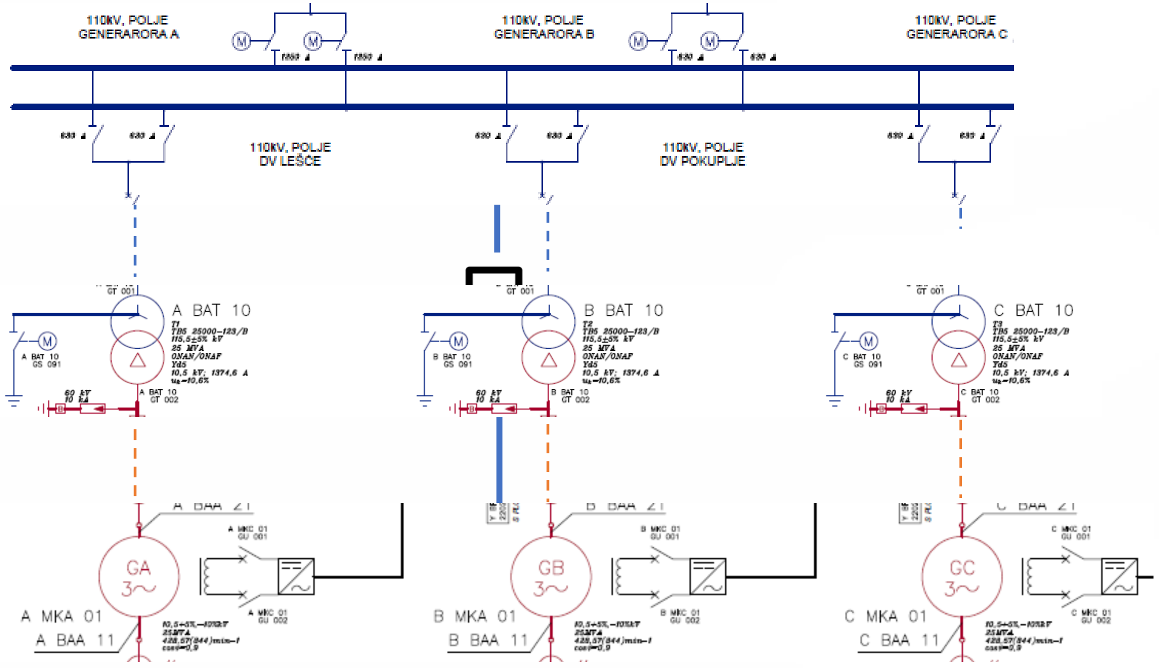


- Dual transformer method
    - Advantages:
        - Monitors 6 bushings
        - No network unbalance problems
        - Faster response
    - Disadvantages:
        - More cabling



Case – power plant for peak loading

- Power plant information
  - Hydro power plant commonly used during peak loading
  - 3 generators
  - 3 step-up transformers (3-phase 25MVA)
  - Transformers connected to same 110 kV busbar
- Challenges
  - 3Phase bank method cannot be used since transformers are rarely on the grid more than a few days and averaging cannot be used to overcome grid imbalance
  - Reference methods must used
  - Data sharing and synchronization of distributed measurements
- Monitoring topology
  - 3 distributed TMS cubicles
    - Connected to the same LAN
    - Each TMS shares measurements with others
    - Each is synchronized to the same time
  - No added complexity and additional expenses
  - Additional feature monitoring of fast transients



Compensation method

- High sensitivity measurements
  - Each device measures bushing leakage currents amplitude and phase angle
  - Phase angle accuracy must be better than 0.01°
  - Leakage current amplitude and phase angle depends on:
    - Bushing C1 capacitance and dissipation factor
    - Grid voltage and phase angles
- HOW IS IT DONE?
  - Grid errors compensated using simple subtractions

$$\frac{\Delta C_{measured}}{C_0} = \frac{\Delta C_{real}}{C_0} + CAP\_ERR_{GRID}$$

$$\Delta tg\delta_{measured} = \Delta tg\delta_{real} + TG\_ERROR_{GRID}$$

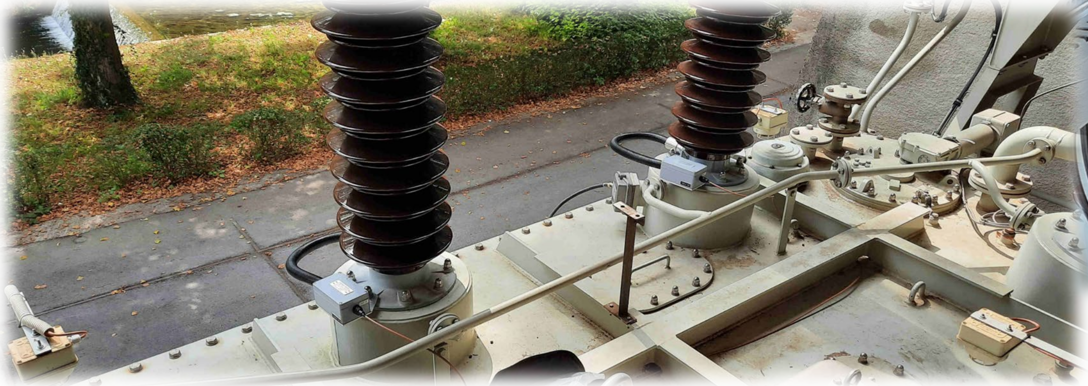
$$\frac{\Delta C}{C_0} = \frac{\Delta C_{DUT}}{C_0} - \frac{\Delta C_{REF}}{C_0}$$

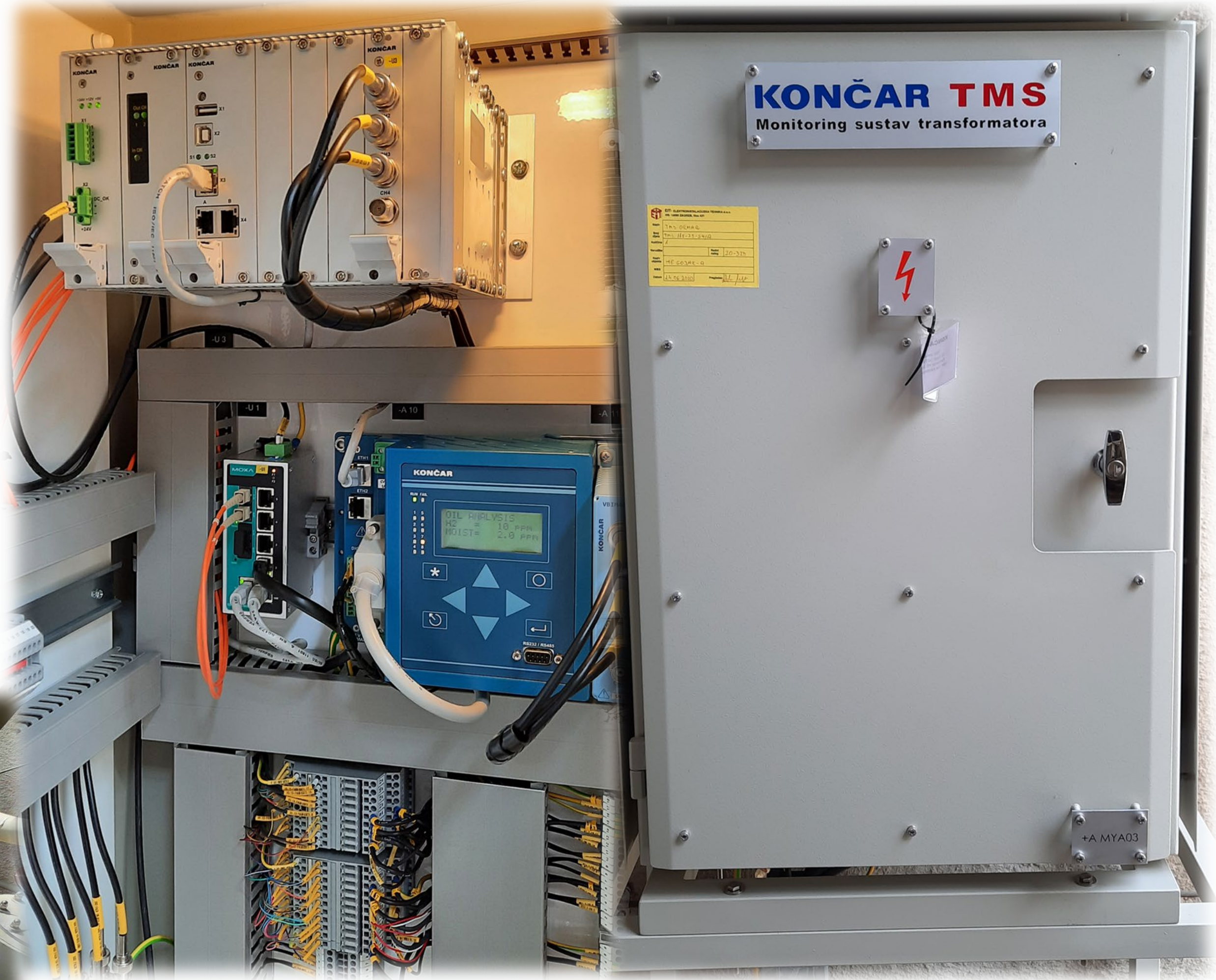
$$\Delta tg\delta = \Delta tg\delta_{DUT} - \Delta tg\delta_{ref}$$

Example - Installation

- OIP Bushings
  - Same Type and Manufacturer on all transformers
  - Periodically checked using offline methods
  - Monitoring installed in 2020

	AT1	AT2	AT3
Phase U	2017	2004	2004
Phase V	1999	2004	2004
Phase W	1999	2004	2004

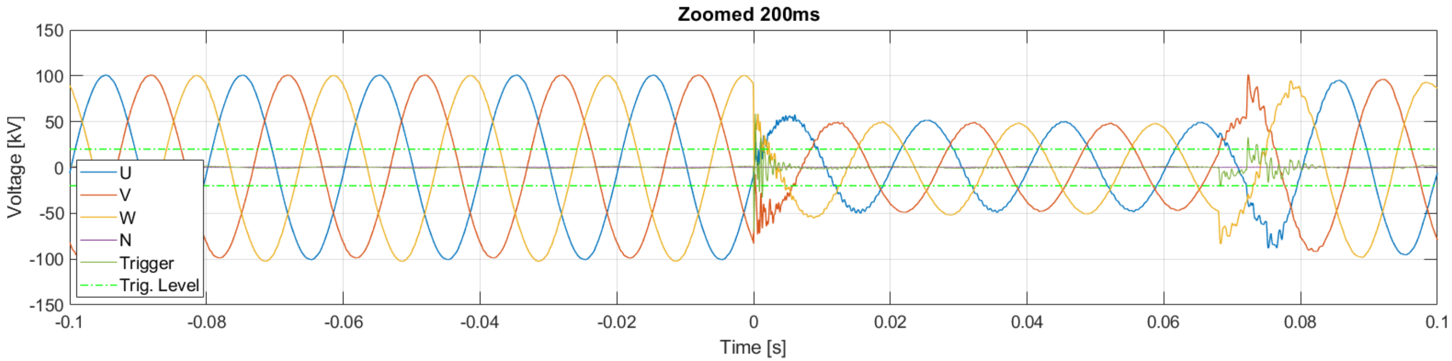


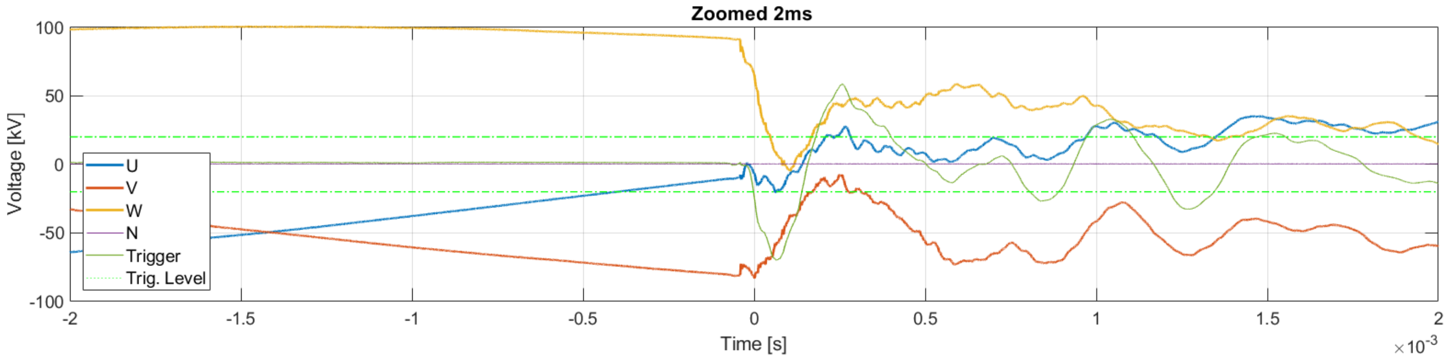


Example – Lightning strikes recorded

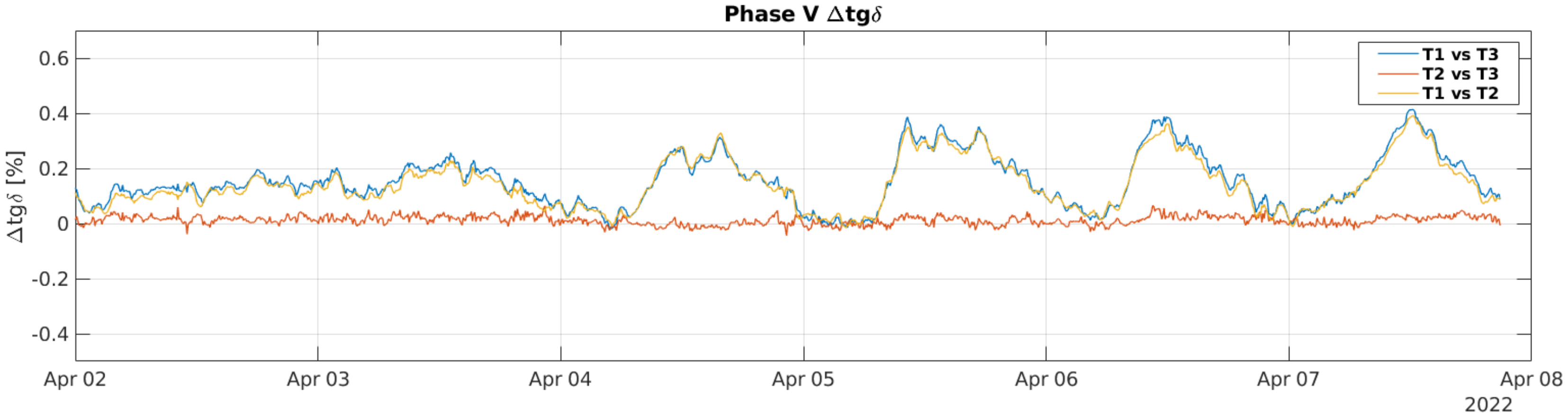
- Transient Recorder Performance
  - 4 - 16 channels @ 5 MSps
  - Rise times > 350 ns
  - Long acquisition time, up to 7 seconds
  - Synchronized time

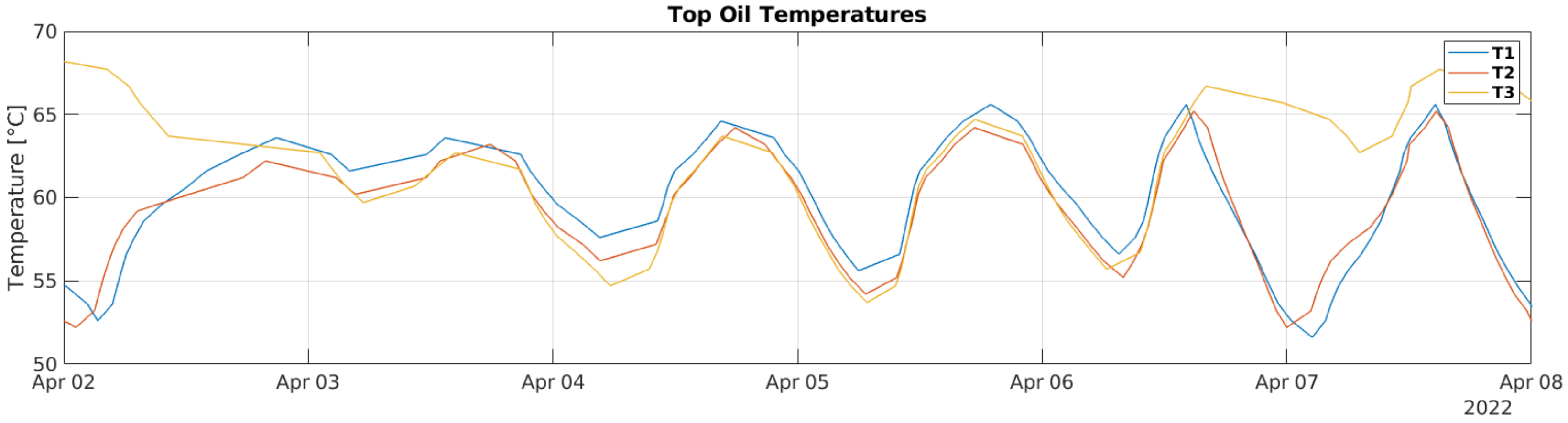
- Transient recorder benefits
  - Overvoltage protection monitoring
  - Overvoltage mapping
  - Insulation stresses assessment
  - Comparison with standard testing impulses
  - Non-standard impulses





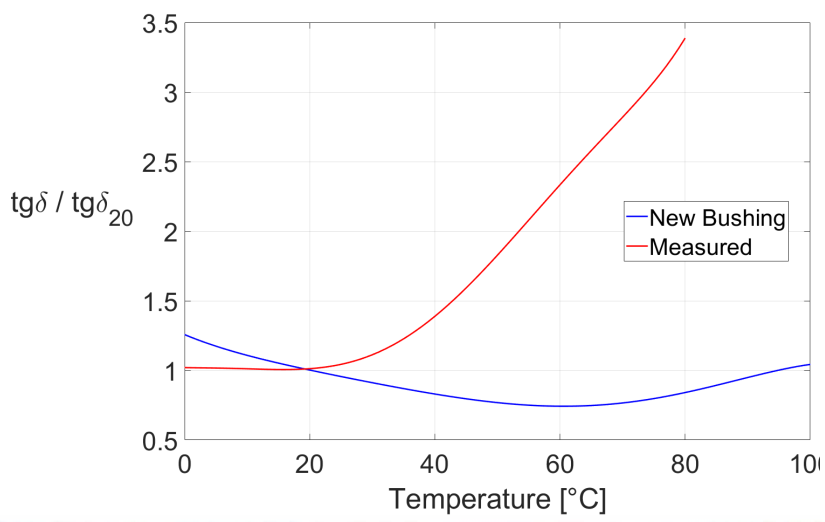
Example - Monitoring Results

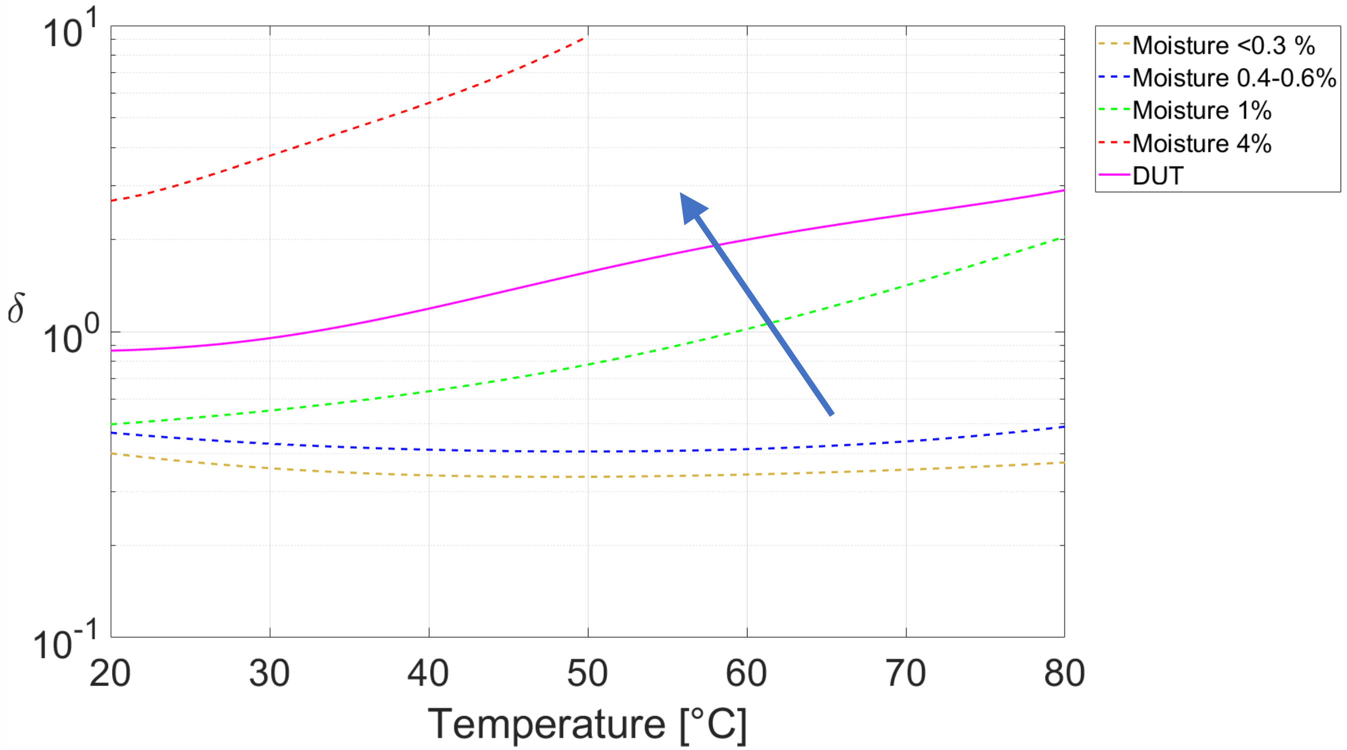




Postmortem analysis – dissipation factor

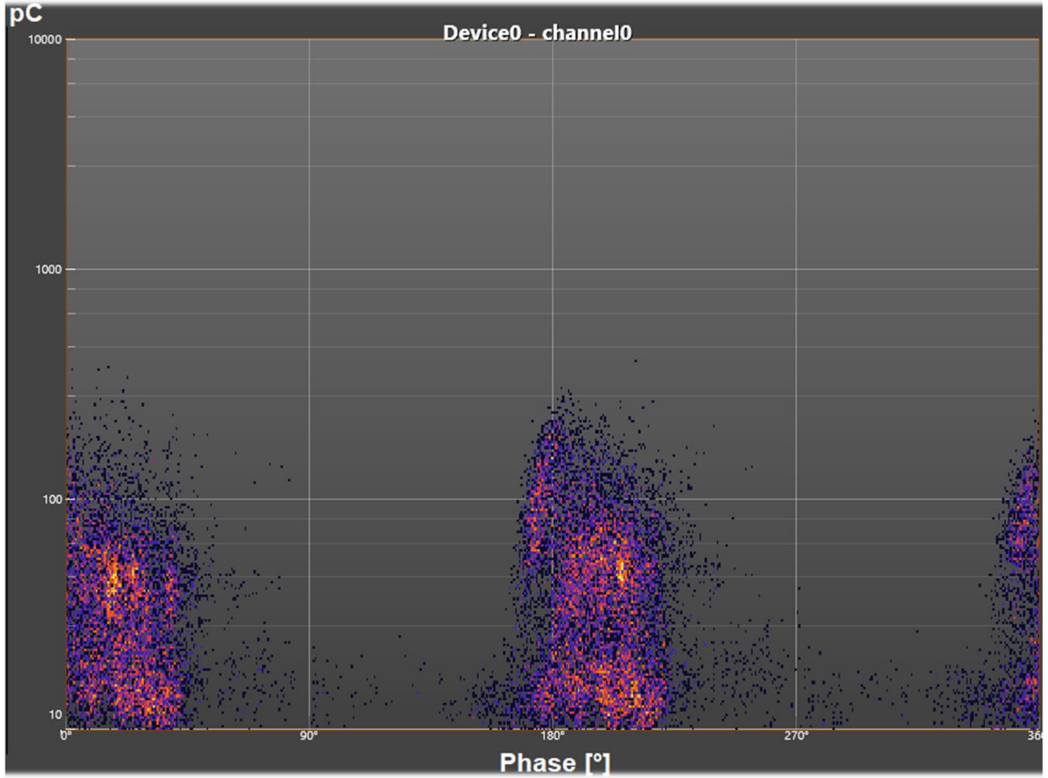
- Dissipation factor temperature dependency
  - Saddle-like curve
  - Curve shape depends on moisture
- Testing faulty bushing in climatic chamber
  - Comparison with manufacturer's data
  - Testing in the range from 0 – 80 °C
- Conclusion
  - Monitoring measurement confirmed





Postmortem analysis - PD

- Insulation deterioration can be assed by measuring PD
- Testing faulty bushing in a high voltage lab
- Partial discharges appearance



THANK YOU FOR YOUR ATTENTION

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