



Title:

New Technologies Applied in Power system Equipment

By:

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Center of Excellence in Power System Management and Control**

**Electrical Engineering Department, Kahroba Hall
18 December, 2022**

- ❑ Brief Introduction of [Reinhausen Group](#)
- ❑ Onload Vacuum Tap Changer ([VACUTAP](#))
- ❑ Onload Tap Changers for Distribution Transformer ([ECOTAP VPD](#))
- ❑ Embedded Transformer Operating system ([ETOS](#))
- ❑ Online [Bushing Monitoring](#)
- ❑ Online Dissolved Gas analysis ([DGA](#))
- ❑ [Fiber Optic Online Temperature Measurement](#)
- ❑ Tap Changer Monitoring ([VAM](#))
- ❑ Silicone [Composite Bushing](#)
- ❑ Composite [Pylon](#)



Reinhausen Group

50% of the generated electric energy in the world passes through our products



+8.000



+1 \$B



3.600



1868



ENERJAN

Onload Vacuum Tap Changer (VACUTAP)

Transformer with OLTC



Energy Consumption
Increases

Car with Cruise Control



Car Drives up a **Steep Hill**

Voltage Regulator
Detects **Voltage Drop**,
Sends **Control Command**
to OLTC



Cruise Control **Detects**
Speed Decrease



OLTC Sets Transformer
Windings to **New**
Transmission Ratio



Gearbox **Shifts Down**
Automatically

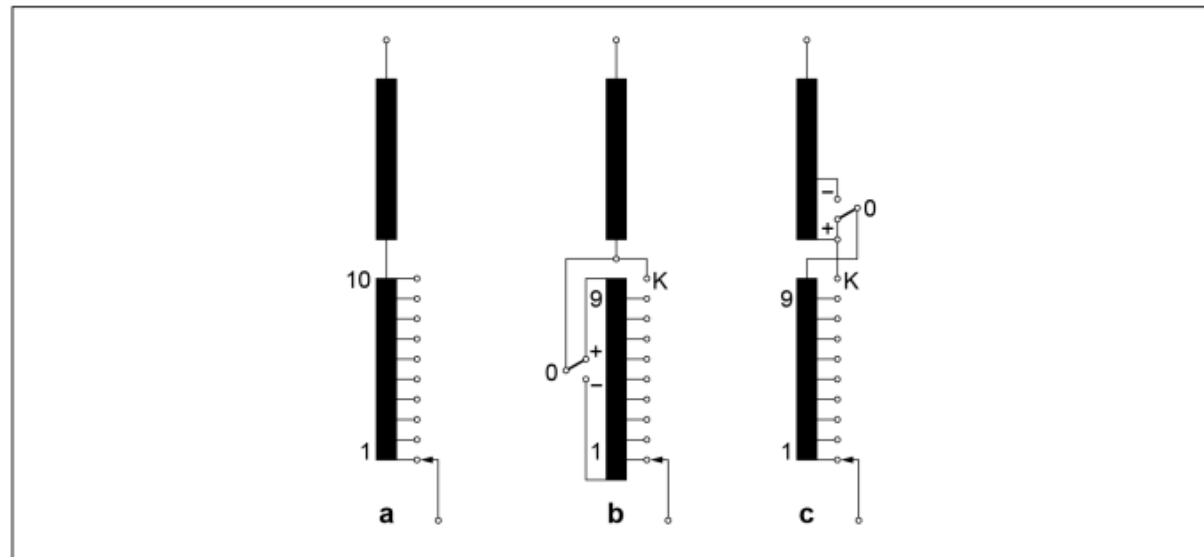
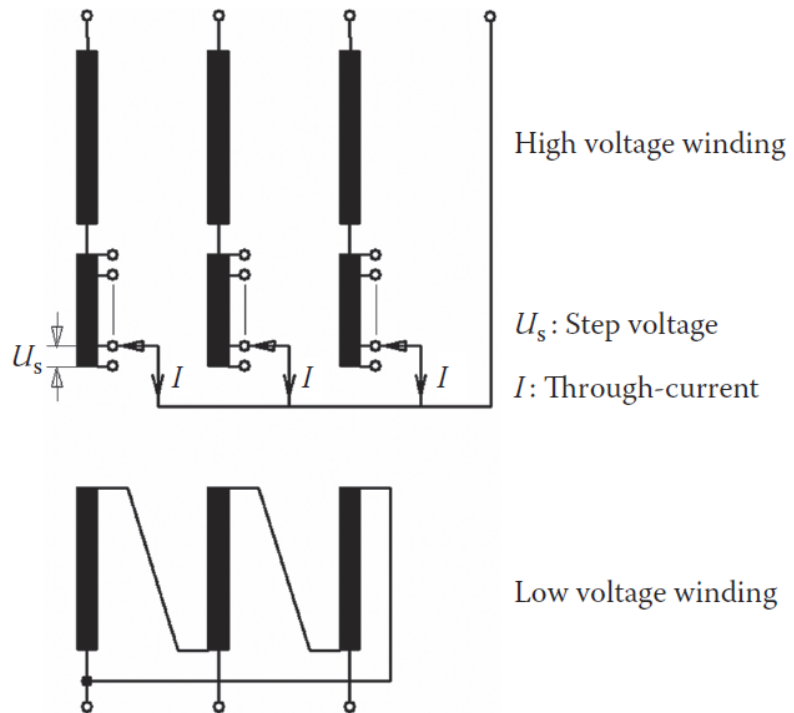


Constant Voltage

Constant Speed



Onload Vacuum Tap Changer (VACUTAP)

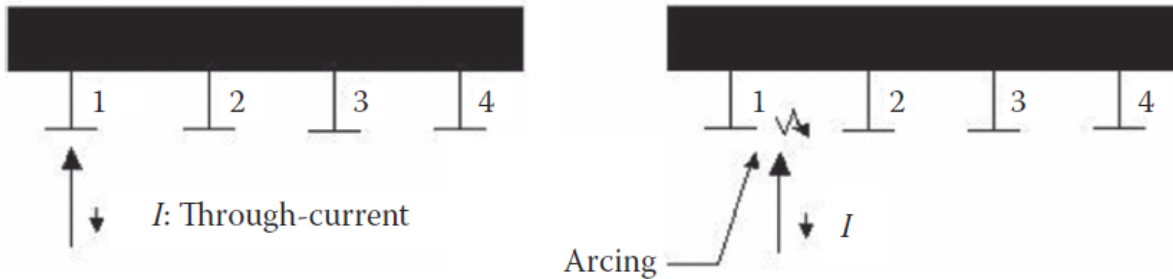


- | | | |
|---|-------------------------------------|-------------|
| a | Without change-over selector | Max +/- 10% |
| b | With reversing change-over selector | |
| c | With coarse change-over selector | |

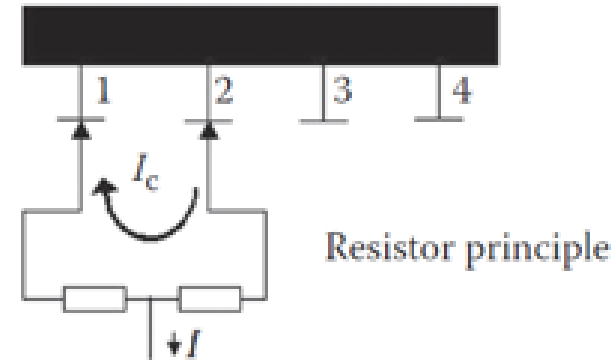
Onload Vacuum Tap Changer (VACUTAP)

Switching

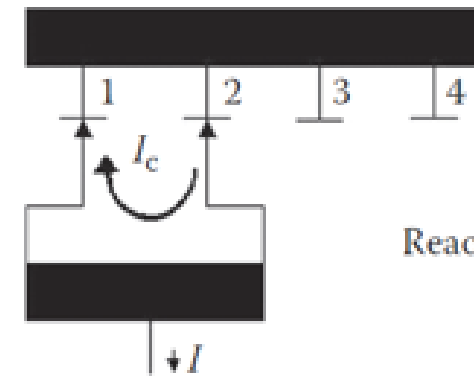
Tap 1 → Tap 2



Total time for a complete tap-change: 3-10 s



Resistor principle



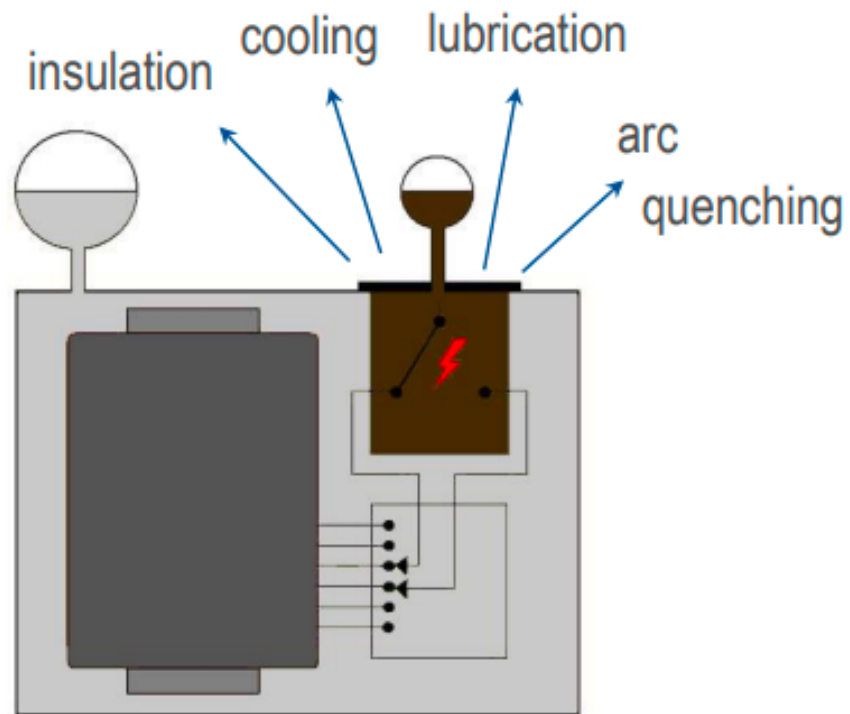
Reactor principle

Just in USA

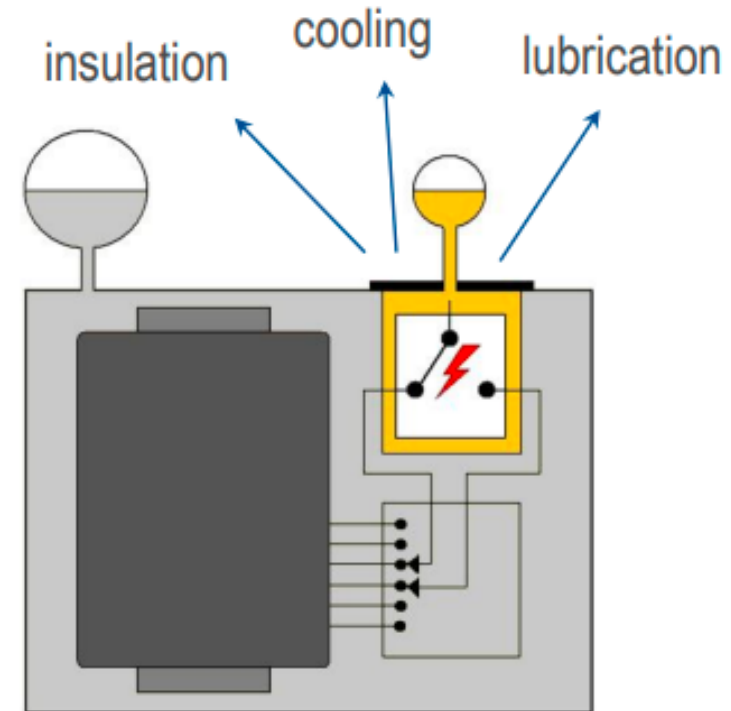


Onload Vacuum Tap Changer (VACUTAP)

Conventional Technology
(OILTAP)



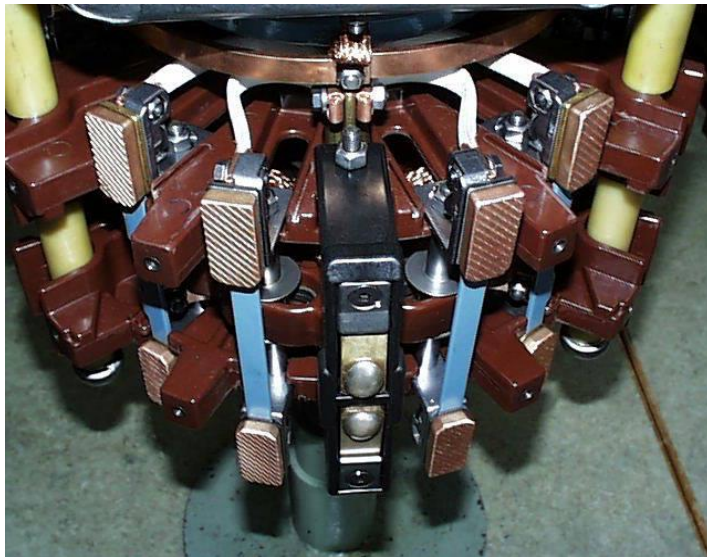
Vacuum Technology
(VACUTAP)



Onload Vacuum Tap Changer (VACUTAP)

Conventional Technology
(OILTAP)

Copper Tungsten Contacts



Vacuum Technology
(VACUTAP)

Vacuum Interrupter



Onload Vacuum Tap Changer (VACUTAP)

- ❑ Oil ageing due to carbon particles resulting from arc quenching
- ❑ Oil filter to be changed regularly
- ❑ Maintenance after 50,000-70,000 operations or after 5-7 years in service
- ❑ No arc in Tap-Changer oil
- ❑ No replacement of oil necessary
- ❑ Inspection after 300,000 operations
- ❑ Replacement of vacuum interrupter after 600,000 operations



Tap-Changer after
80,000 operations



Tap-Changer after
300,000 operations

Onload Vacuum Tap Changer (VACUTAP)

Transformer	Transformer Data			Number of On-Load Tap Changer Operations per Year		
	Power MVA	Voltage kV	Current A	Min.	Medium	Max.
Power station	100–1,300	110–765	100–2,000	500	3,000	10,000
Interconnected	200–1,500	110–765	300–3,000	300	5,000	25,000
Network	15–400	60–525	50–1,600	2,000	7,000	20,000
Electrolysis	10–300	20–110	50–3,000	10,000	30,000	150,000
Chemistry	1.5–80	20–110	50–1,000	1,000	20,000	70,000
Arc furnace	2.5–150	20–230	50–1,000	20,000	50,000	300,000



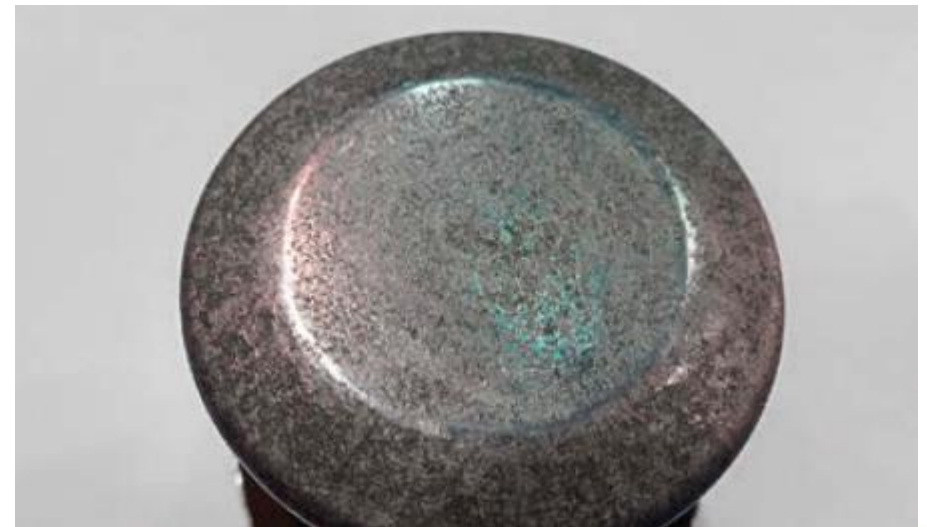
Onload Vacuum Tap Changer (VACUTAP)

Opened Vacuum Interrupters

After 300,000 Operations in Arc
Furnace Transformer

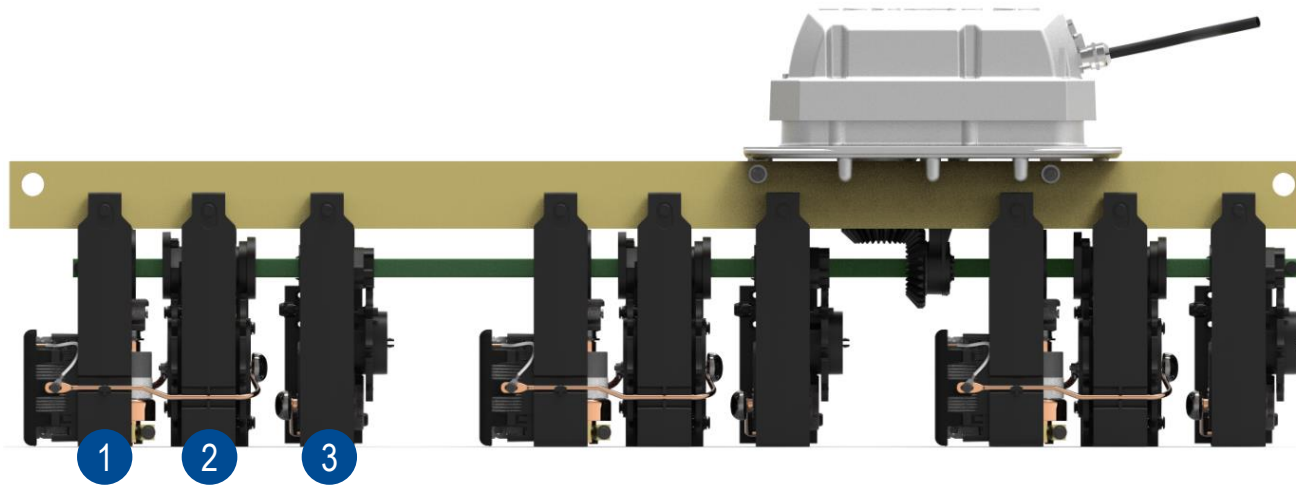


After 1,800,000 Operations in Arc
Furnace Transformer



Onload Tap Changers for Distribution Transformer (ECOTAP VPD)

- ❑ The **smallest** resistor-type OLTC in the **world**



- (1) Switching module
- (2) Selector module
- (3) Change-over selector module



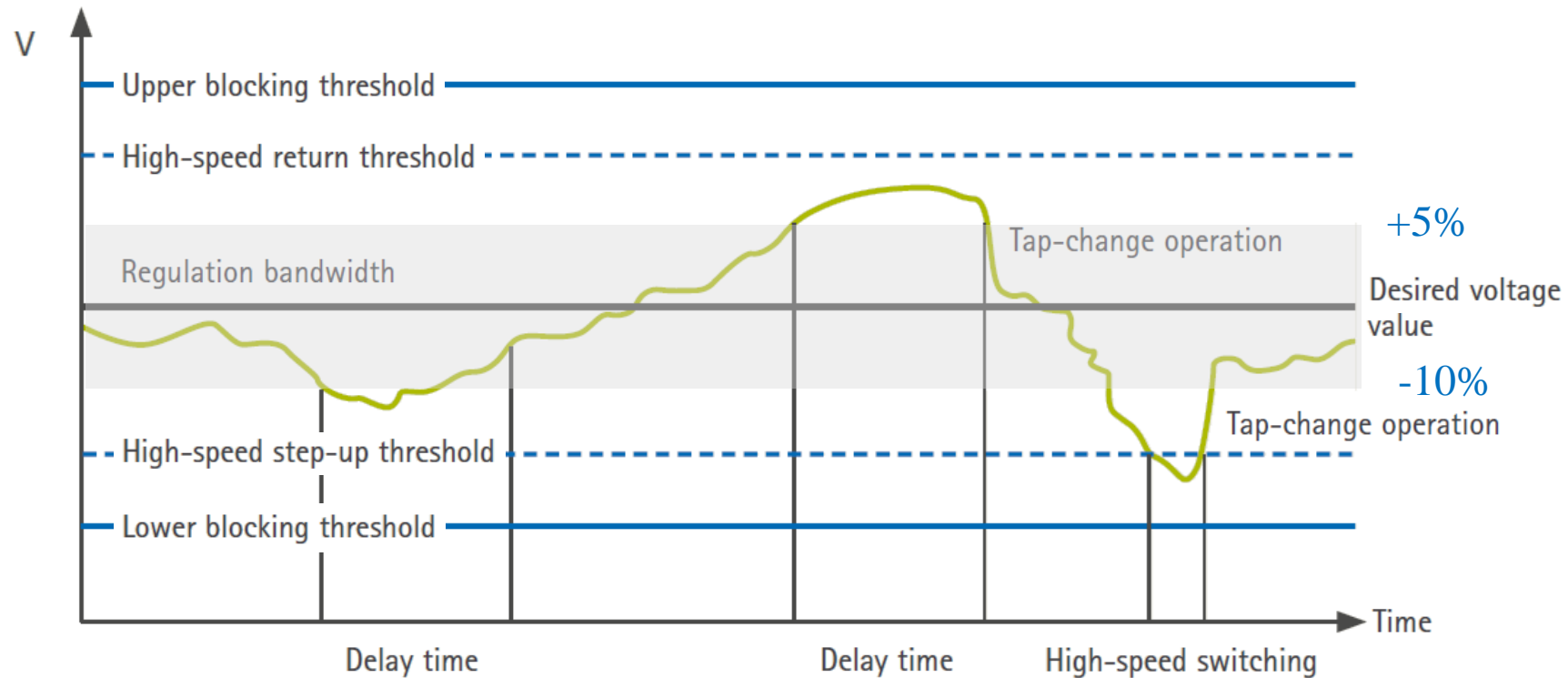
Onload Tap Changers for Distribution Transformer (ECOTAP VPD)

	Grid applications	Universal applications
Max. rated through-current	30 A	100 A
Max. rated step voltage	550 V	825 V
Highest voltage for equipment U_m	24 kV	36 kV, 40.5 kV
Max. number of operating positions	9	9 without change-over selector 17 with change-over selector

Total time for a complete tap change: 2-3 s

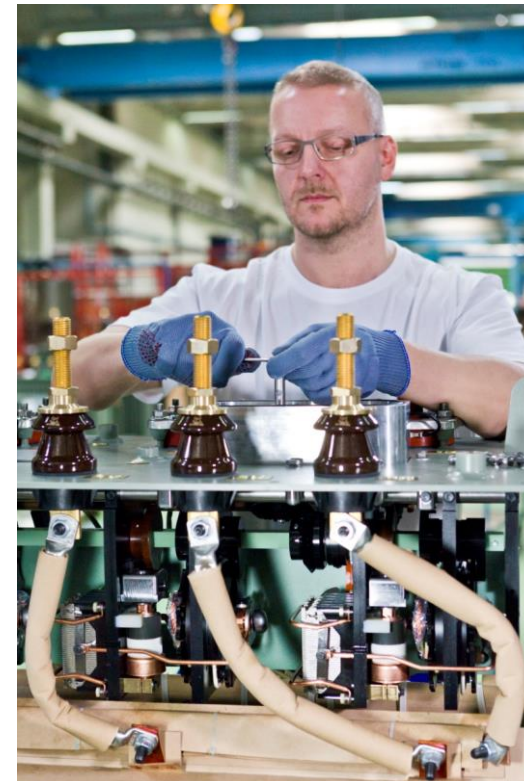


Onload Tap Changers for Distribution Transformer (ECOTAP VPD)



Onload Tap Changers for Distribution Transformer (ECOTAP VPD)

Slight height change in design

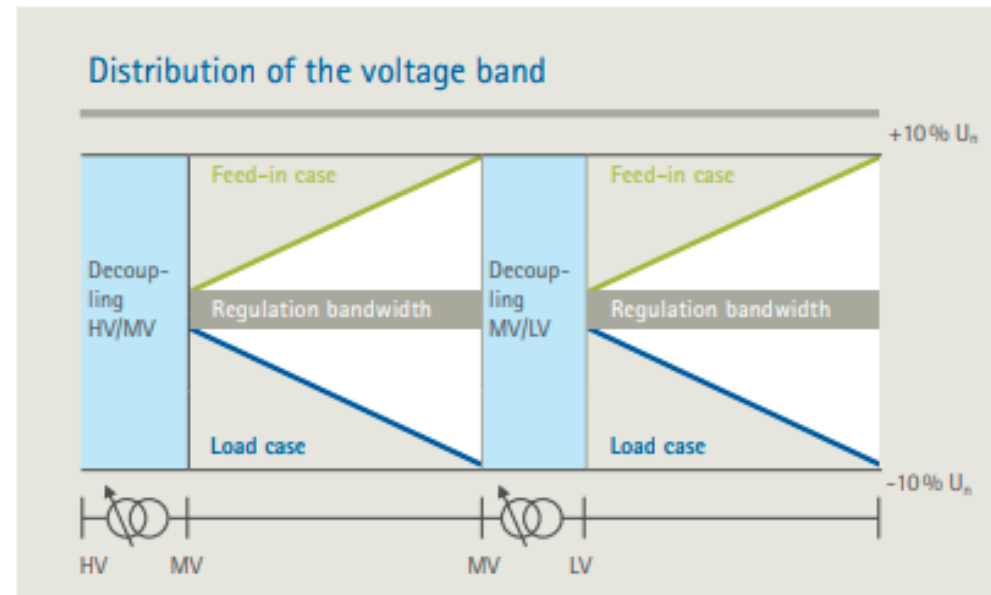
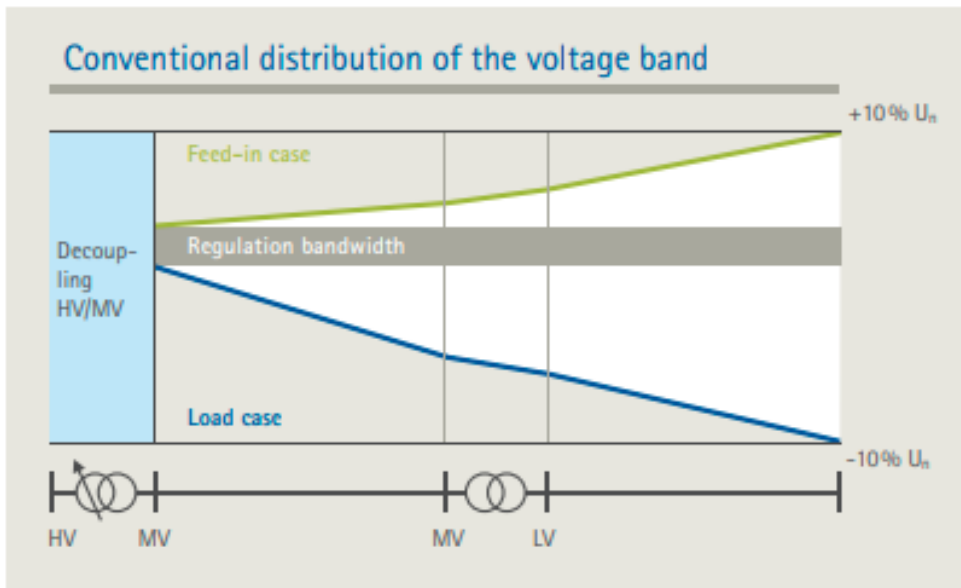


Onload Tap Changers for Distribution Transformer (ECOTAP VPD)

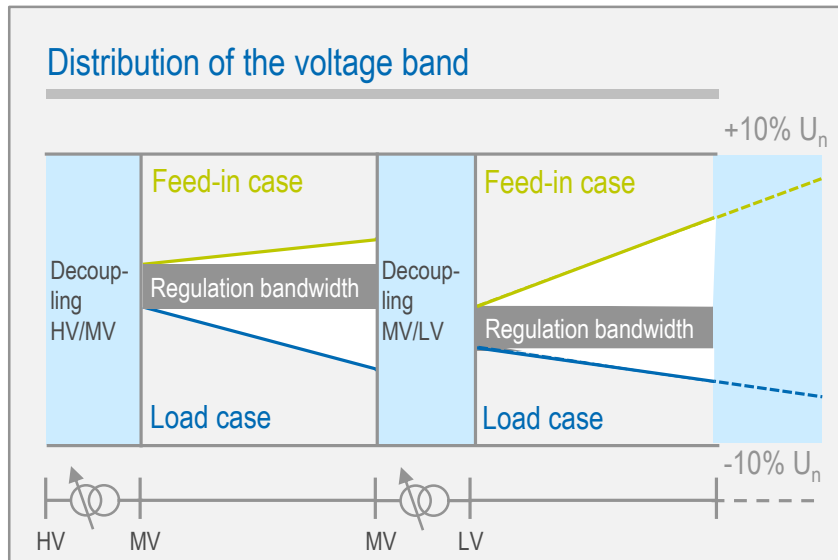
- ❑ For regulation of **distribution** grids with **electric vehicle charging**
- ❑ as well as for **industrial** and **renewable** (wind power, solar) applications



Onload Tap Changers for Distribution Transformer (ECOTAP VPD)



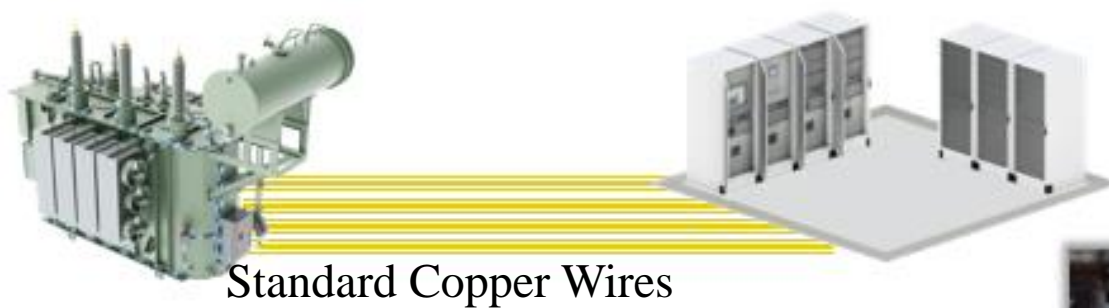
Onload Tap Changers for Distribution Transformer (ECOTAP VPD)



Onload Tap Changers for Distribution Transformer (ECOTAP VPD)



Embedded Transformer Operating system (ETOS)

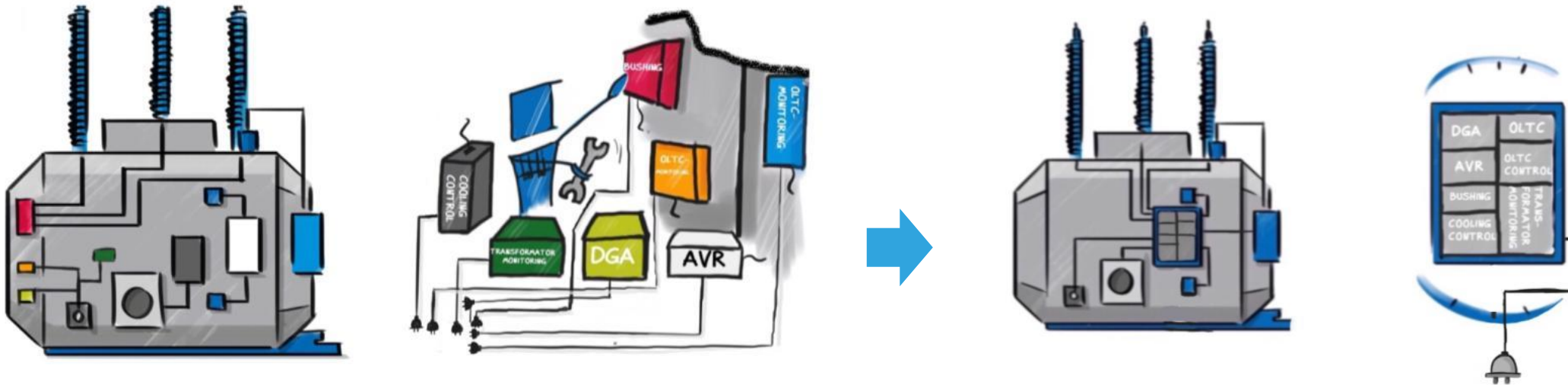


- ❑ Conventional connection: High wiring efforts

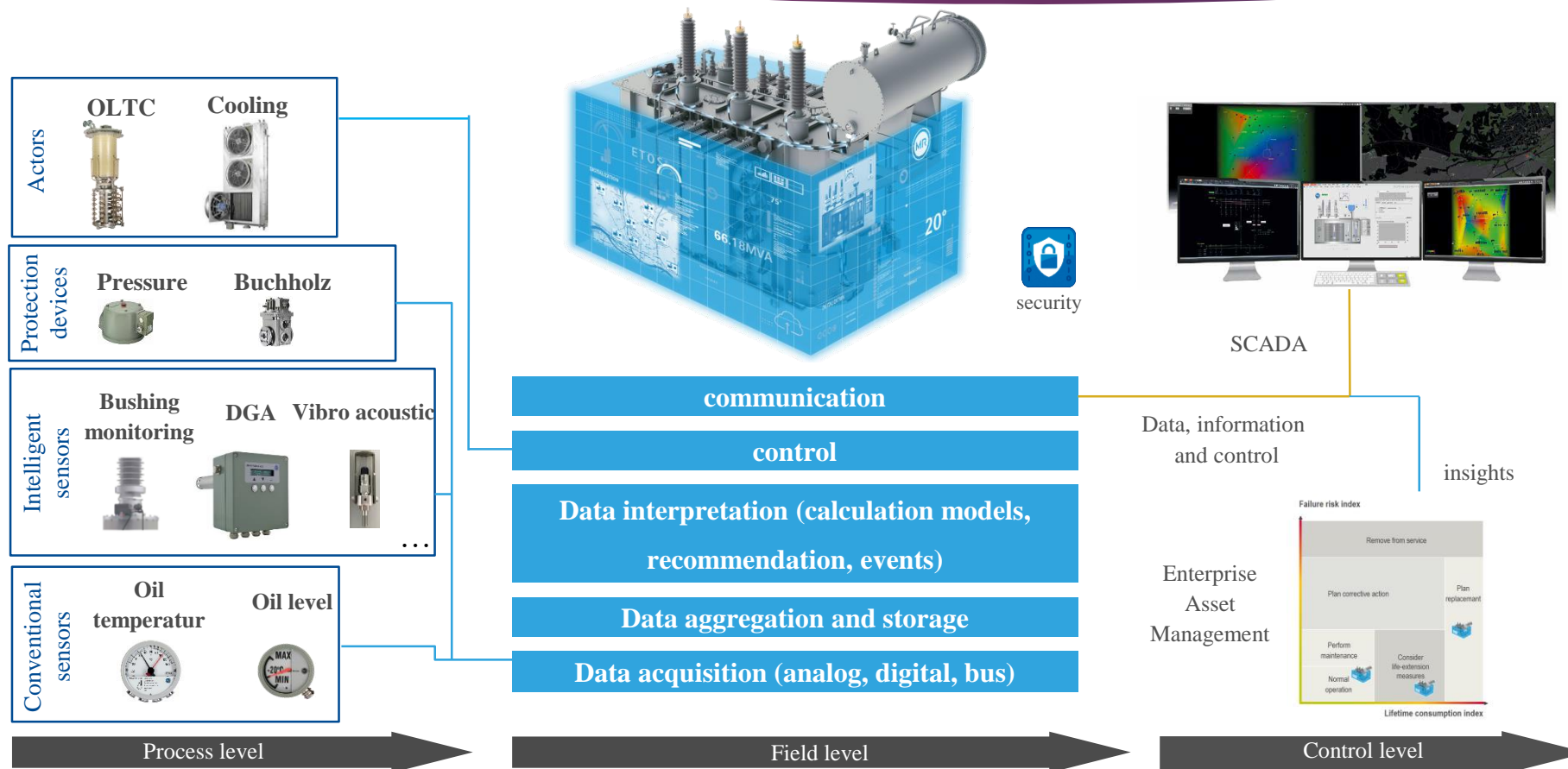


Substation Building

Embedded Transformer Operating system (ETOS)



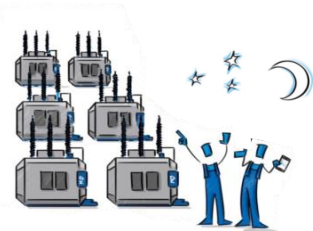
Embedded Transformer Operating system (ETOS)



Embedded Transformer Operating system (ETOS)



Time-based maintenance means that services often come too early or too late, and critical components may be overlooked



Intransparent transformer condition causes high risks of ad-hoc trouble

Replacement & Capital Planning

Monitoring

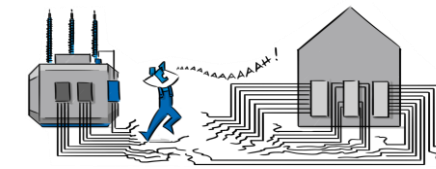
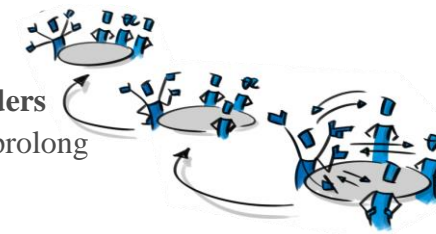
Specification & Design

Commissioning

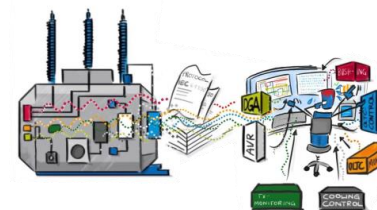
Operation

Heterogeneity of systems makes management really difficult

Many stakeholders complicate and prolong coordination

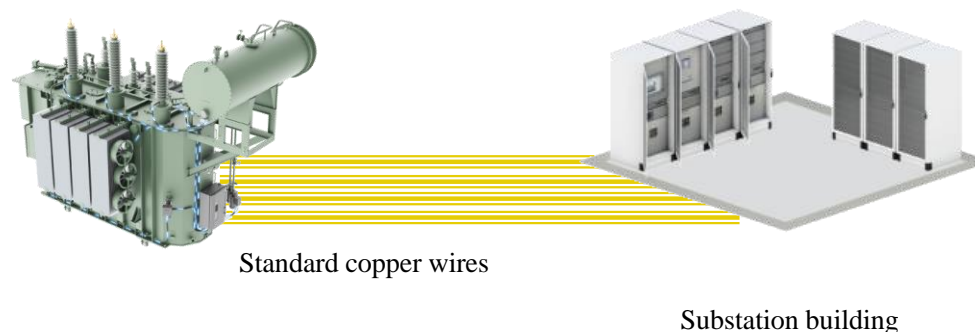


High wiring efforts cost time and increase the probability of errors

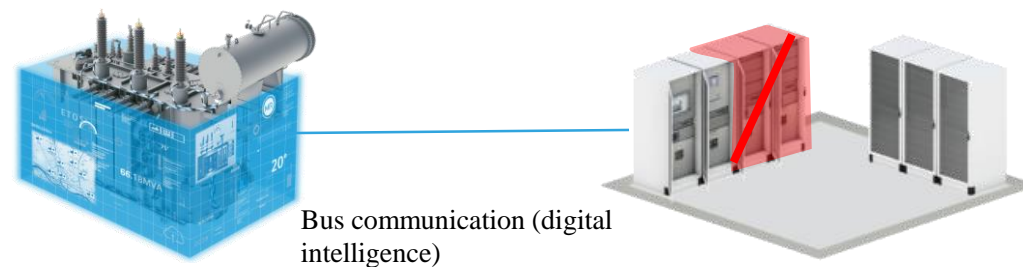


Embedded Transformer Operating system (ETOS)

**Conventional connection:
High wiring efforts**



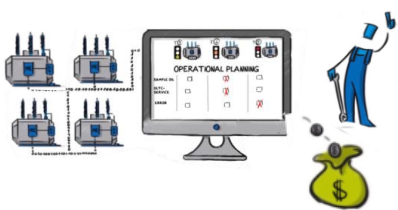
**New connection:
Reliable and efficient
integration**



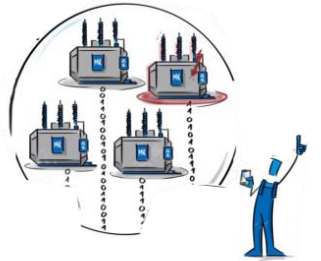
Connection of an „intelligent“ transformer saves up to 70% of conventional costs



Embedded Transformer Operating system (ETOS)



Data-based maintenance allows you to act exactly when needed and to focus your resources on critical assets



Fully transparent transformer condition secures advanced operational reliability

Replacement & Capital Planning

Monitoring

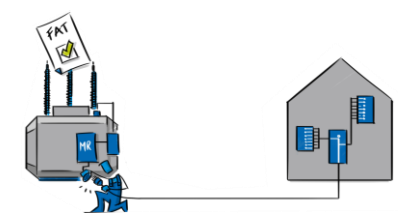
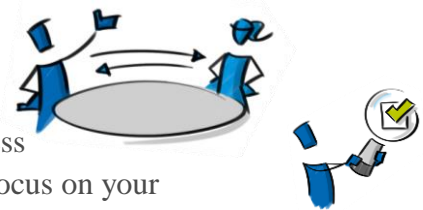
Operation



Specification & Design

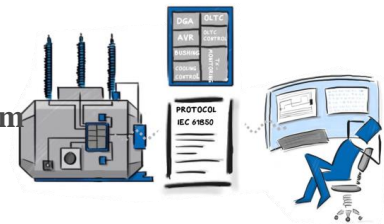
Comissioning

One partner speeds up the process and allows you to focus on your priorities



Simple connection with less cables accelerates mounting and prevents errors

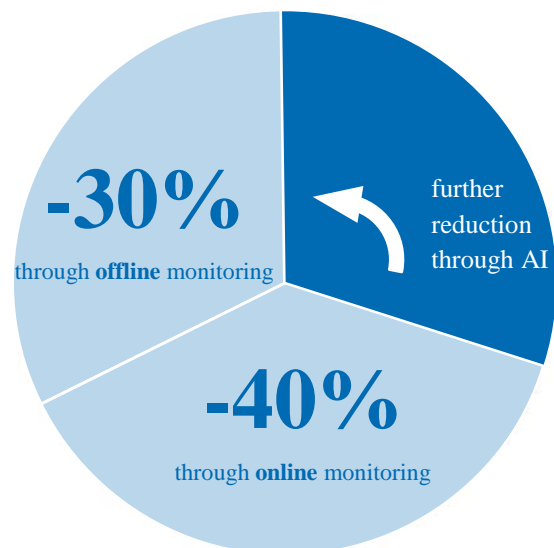
One interface to the entire system makes it easy and intuitive to manage



Embedded Transformer Operating system (ETOS)

Combined off- and online monitoring reduces failure risk by 70%

Transformer failure rate



| Total number of failures peaks at transformer ages of 30 – 40 years



| Routine offline inspections reduce the failure rate by 30%



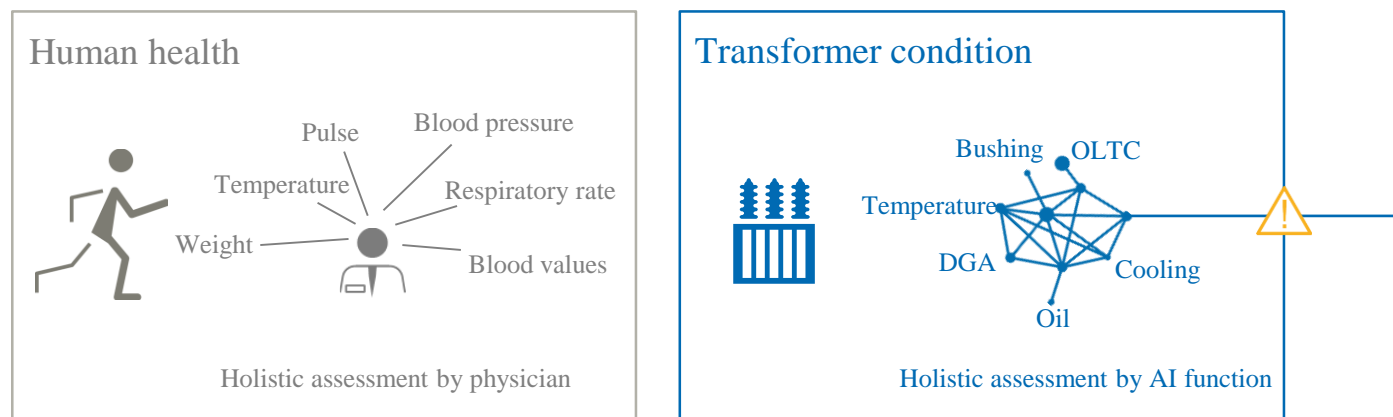
| Additional online monitoring reduce

the failure rate by further 40%
| Artificial Intelligence and algorithms allows further failure reduction



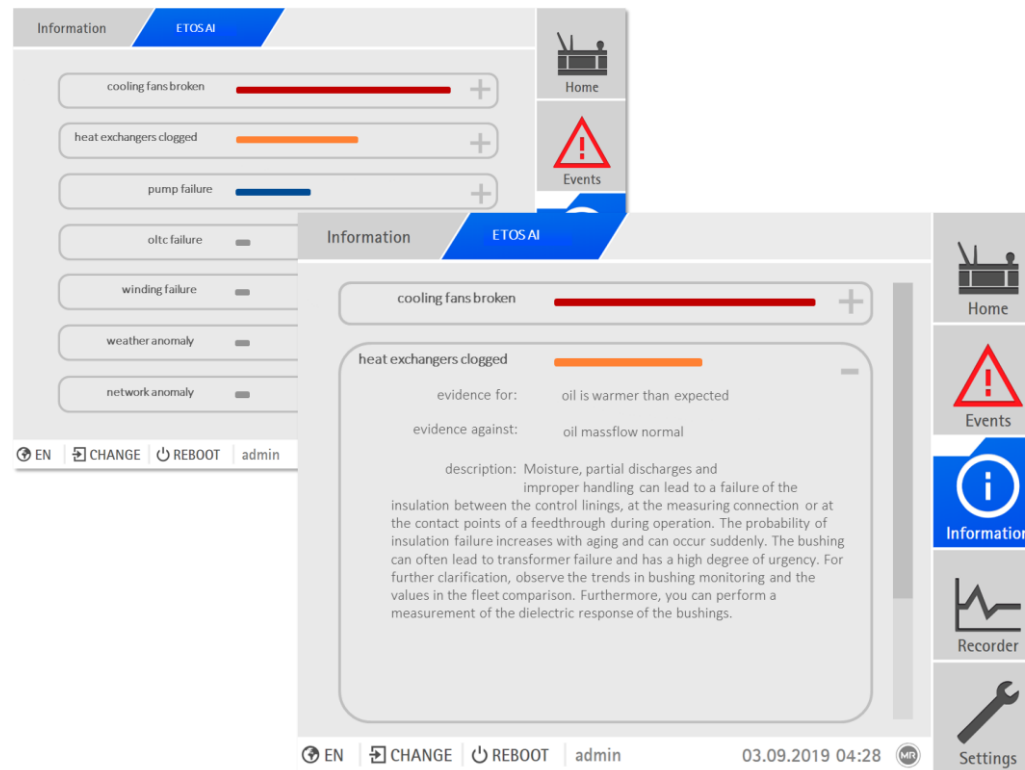
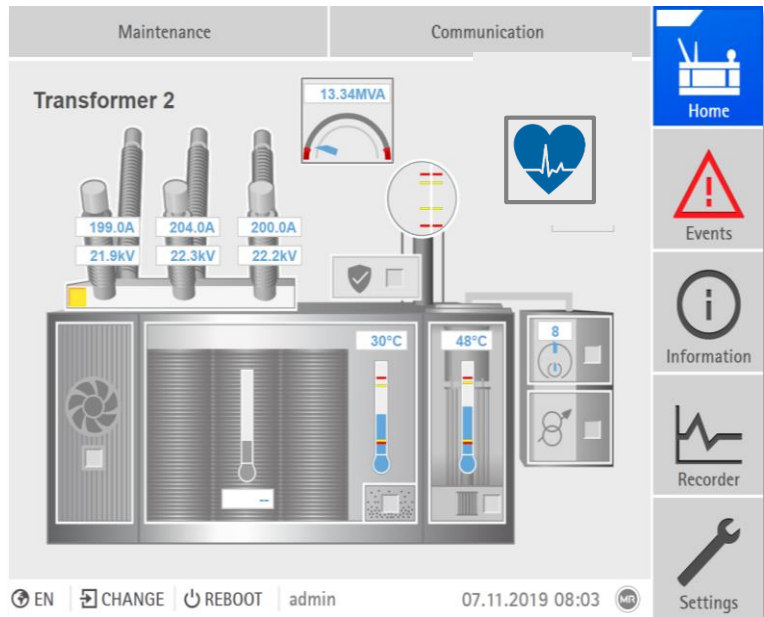
Embedded Transformer Operating system (ETOS)

Our innovative AI function merges individual data into actionable insights



Embedded Transformer Operating system (ETOS)

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Embedded Transformer Operating system (ETOS)

First choose your
ETOS® Design

Integration solution in the motor drive unit



ETOS® TD
innovative top
drive



ETOS® ED classical
drive (mechanical
linkage)

Stand-alone variant



ETOS®

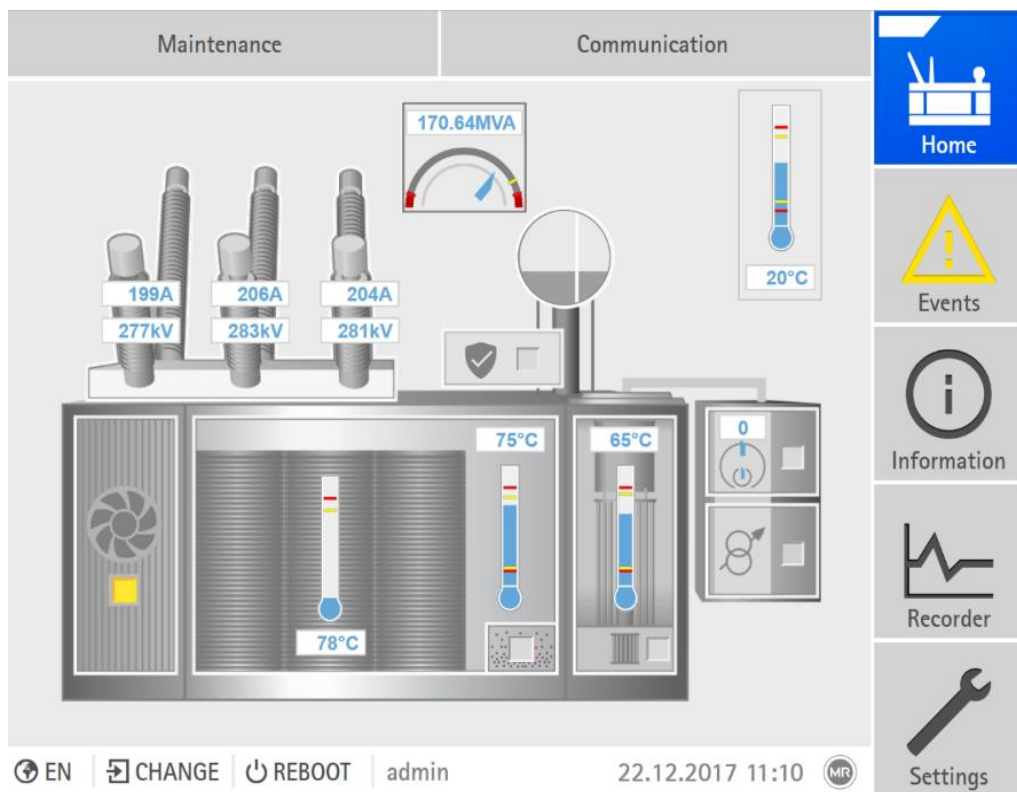
Integration solution into client control cabinet



ETOS® IM
plug-inmodules



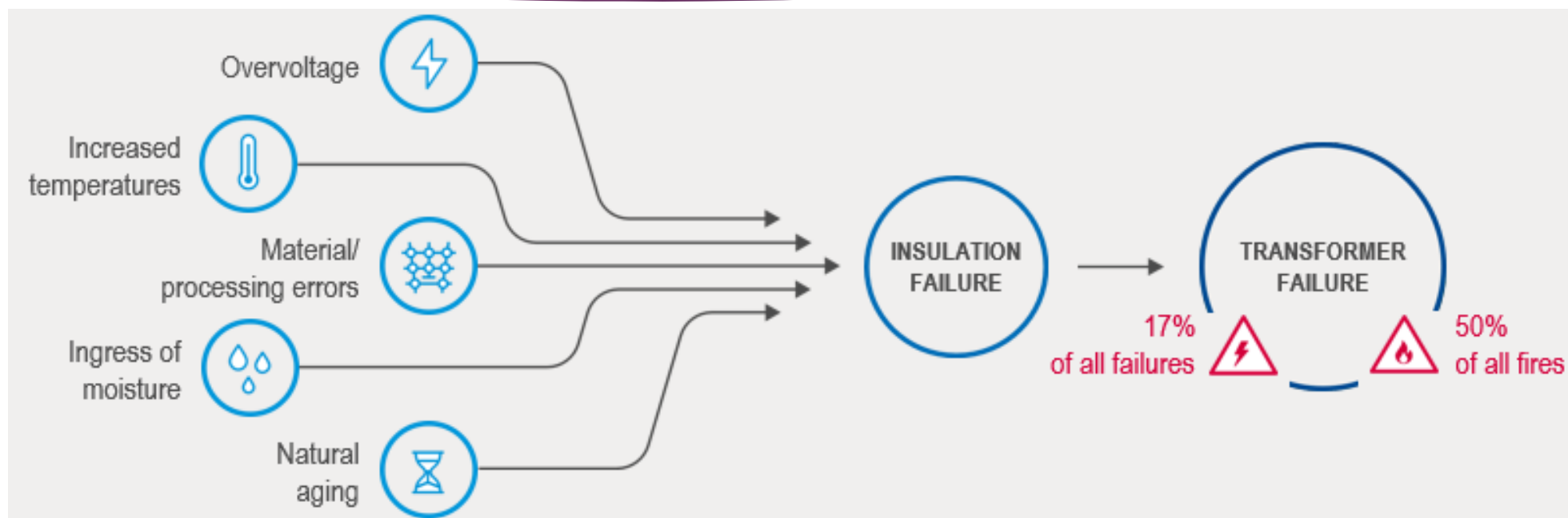
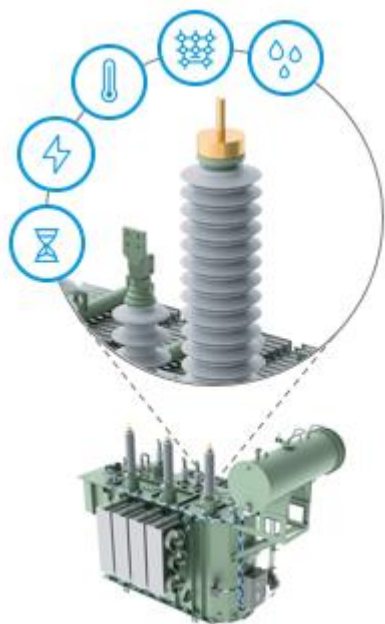
Embedded Transformer Operating system (ETOS)



Visit: <https://demoetos.reinhausen.com>

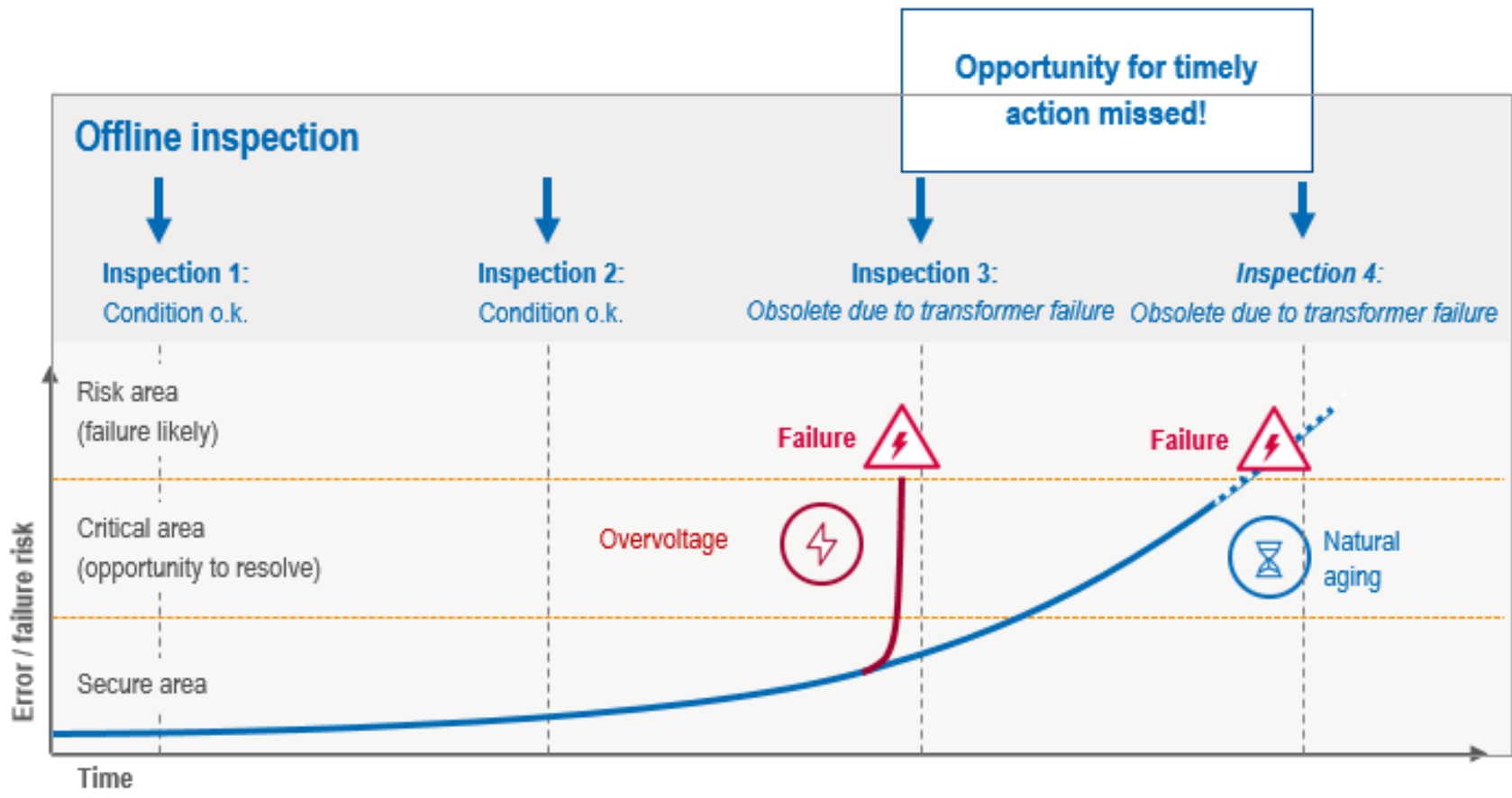


Online Bushing Monitoring

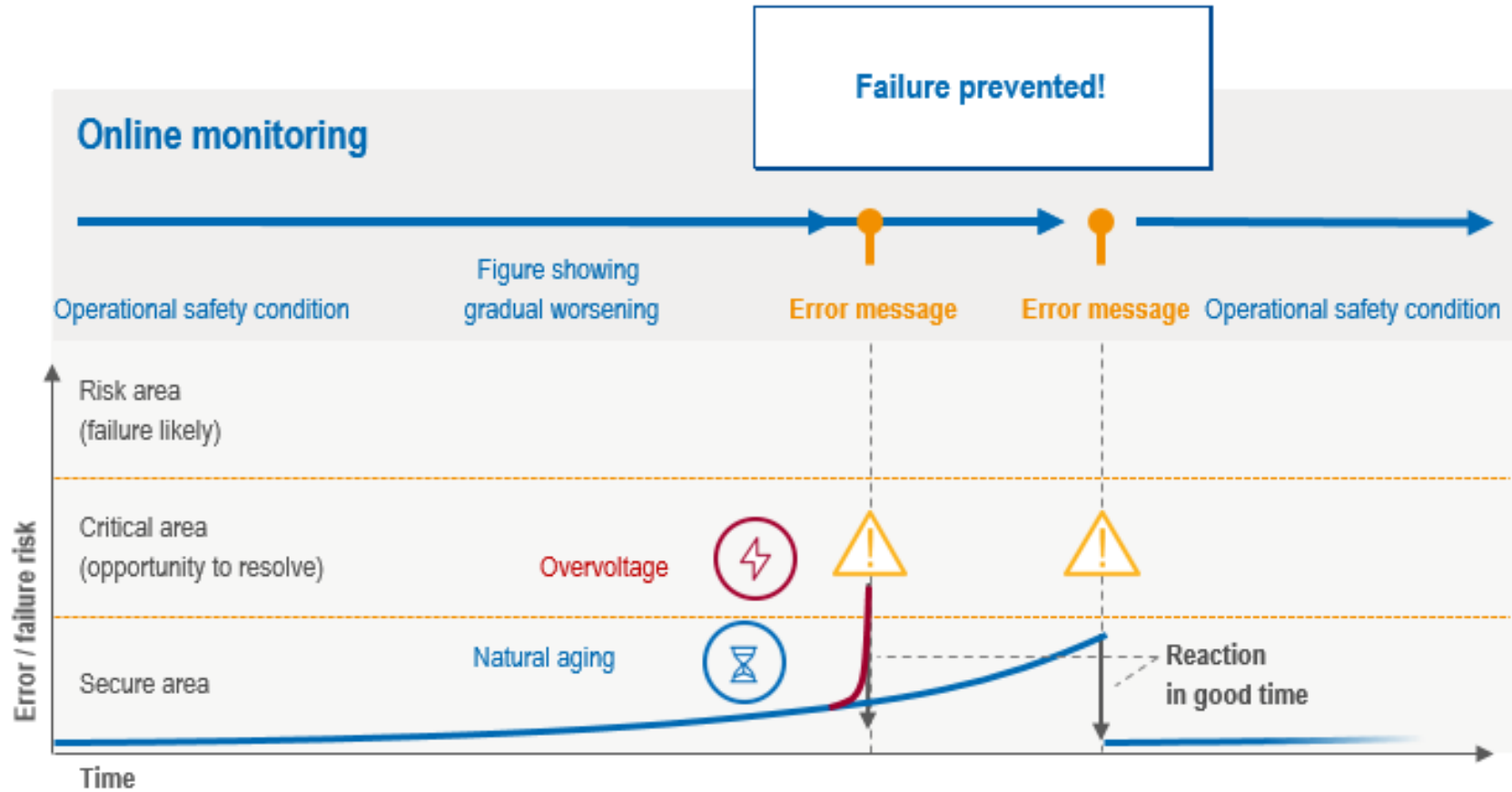


- Typical lifetime of bushings is 25-30 years, therefore bushings have to be replaced once during the lifetime of a power transformer

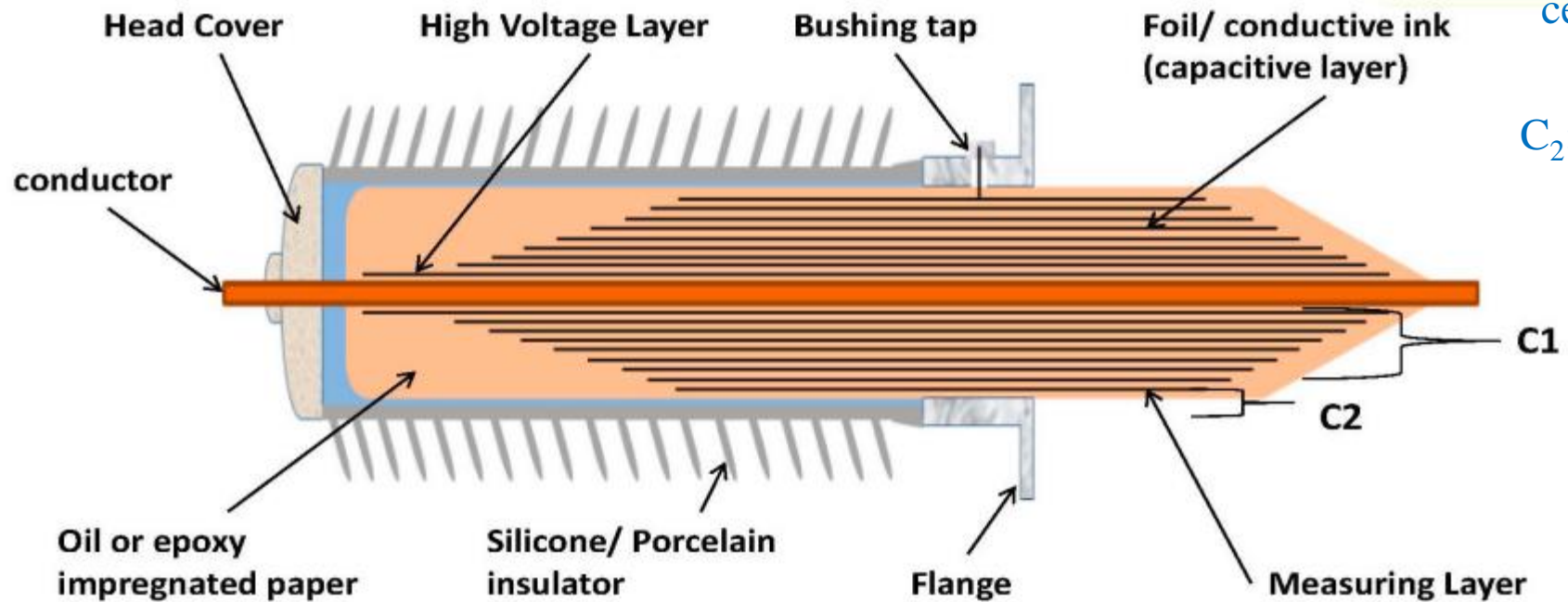
Online Bushing Monitoring



Online Bushing Monitoring



Online Bushing Monitoring

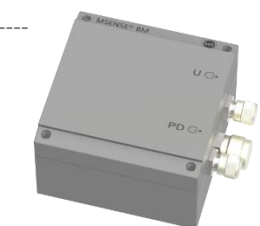
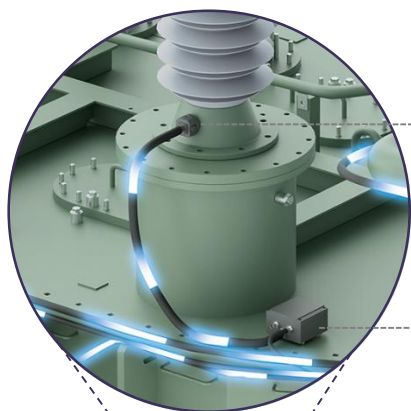


C_1 : capacitance between the center conductor and the tap

C_2 : capacitance from the tap to ground



Online Bushing Monitoring



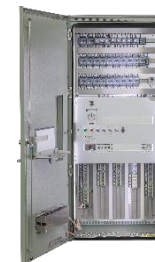
coupling unit

Adaptation of the measured voltage (measuring capacitor)

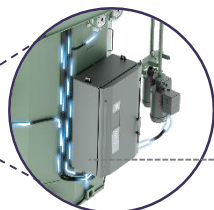
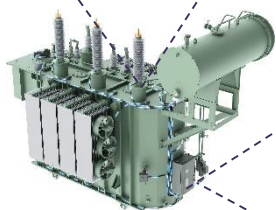


Bushing adapter

Detection of the measured voltage at the test tap of the bushings

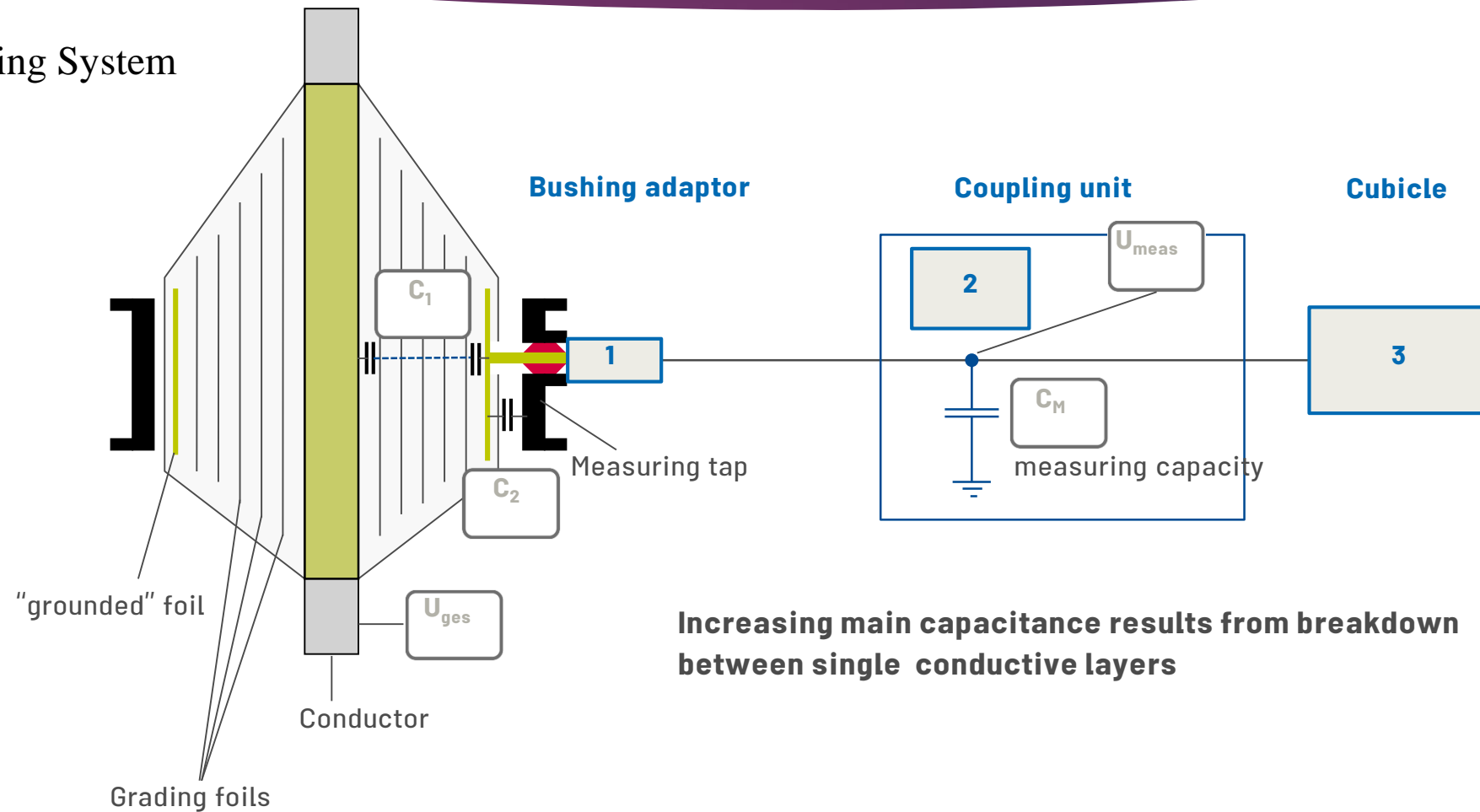


Control cabinet and evaluation unit

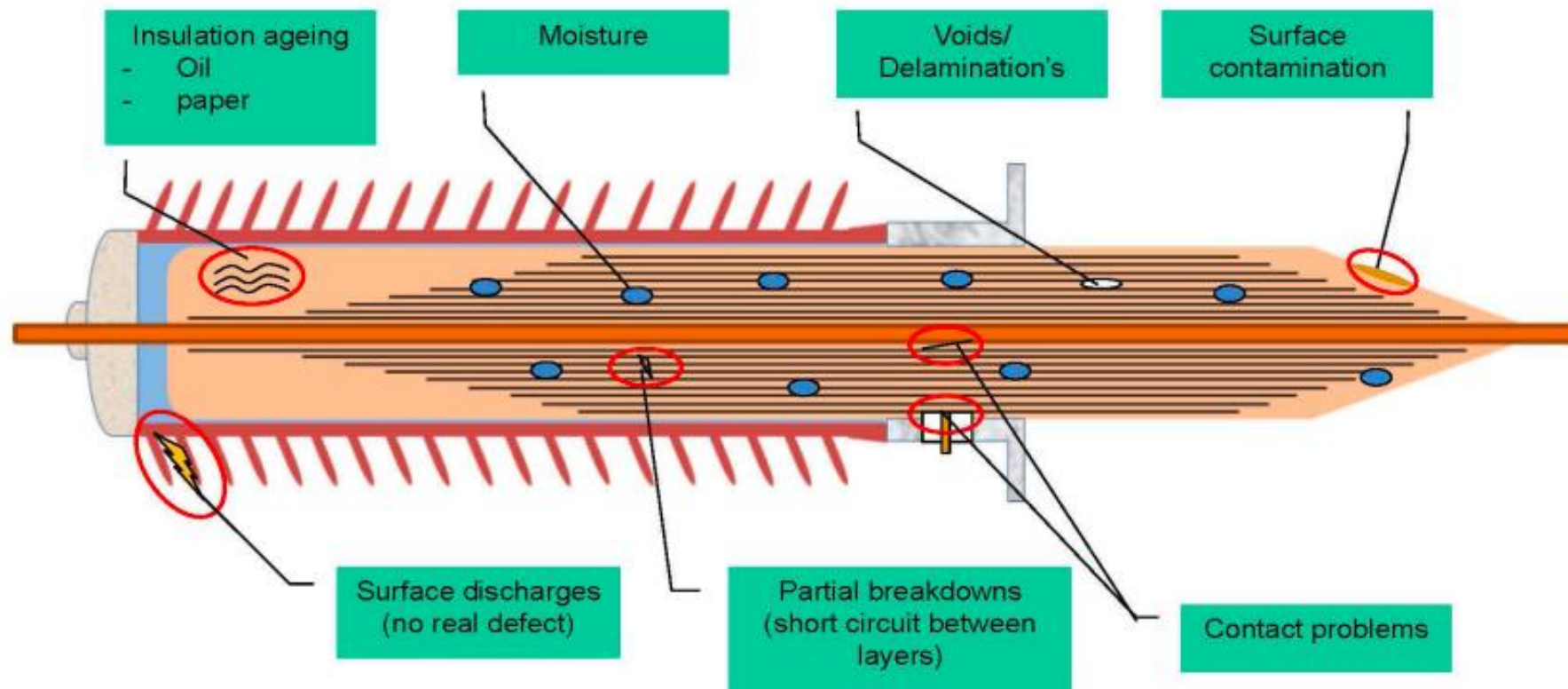


Online Bushing Monitoring

Measuring System



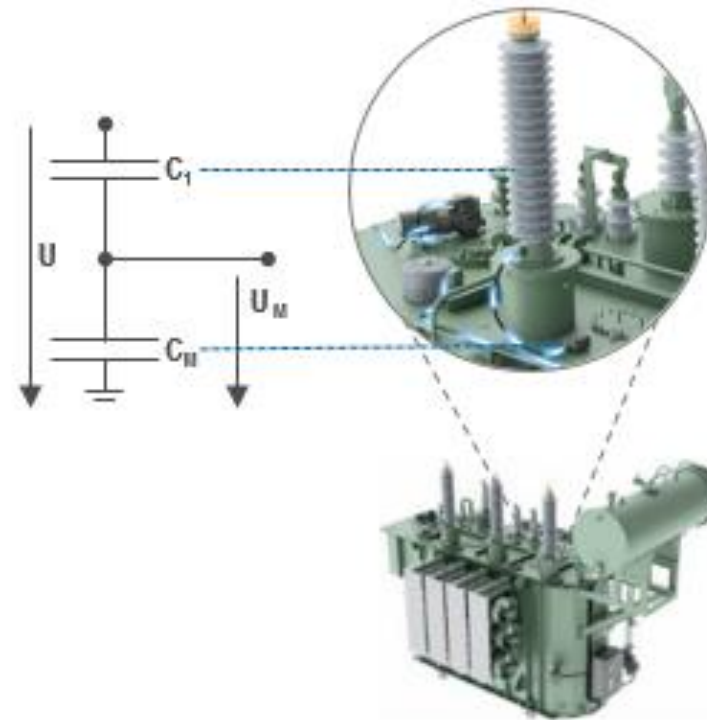
Online Bushing Monitoring



Online Bushing Monitoring

For mainly stable grid structures.

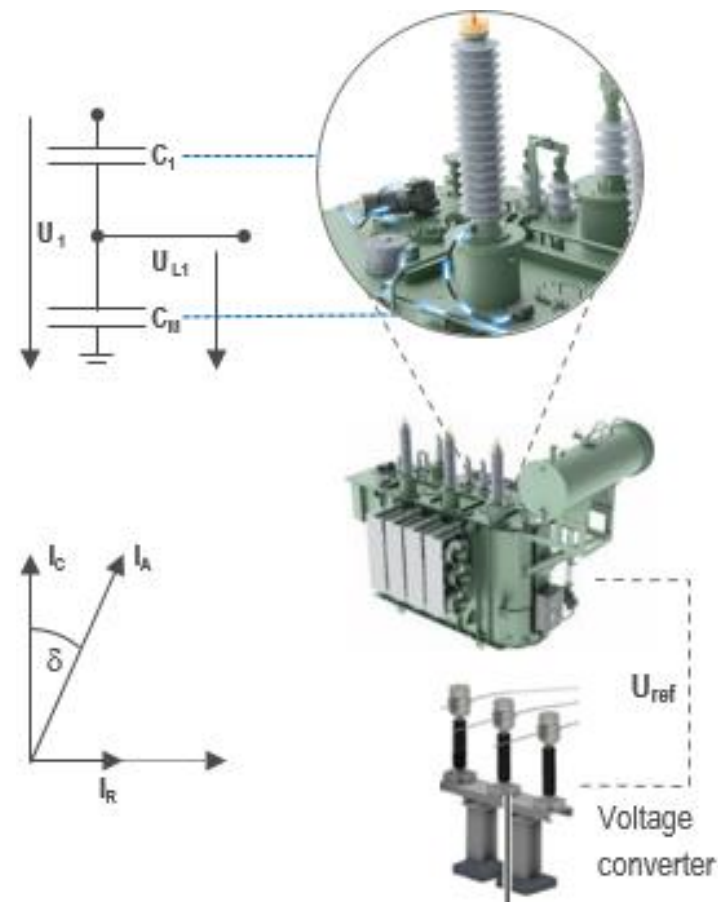
- ❑ Capacitance C_1 of the bushing is compared to a precision capacitance C_M
- ❑ C_M is defined specifically for every use case



Online Bushing Monitoring

With expected grid asymmetries

- the dissipation factor ($\tan \delta$) is analyzed from the reference voltage (U_{ref}) based on the calculated current vector



Online Bushing Monitoring



- ❑ The 2/3 reference algorithm from MR compares the bushings in pairs respectively. This means that only changes that are actually due to aging and damage are recorded.

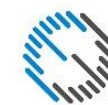


- ❑ Environmental influences and operating conditions influence capacitance and the dissipation factor of the bushings.



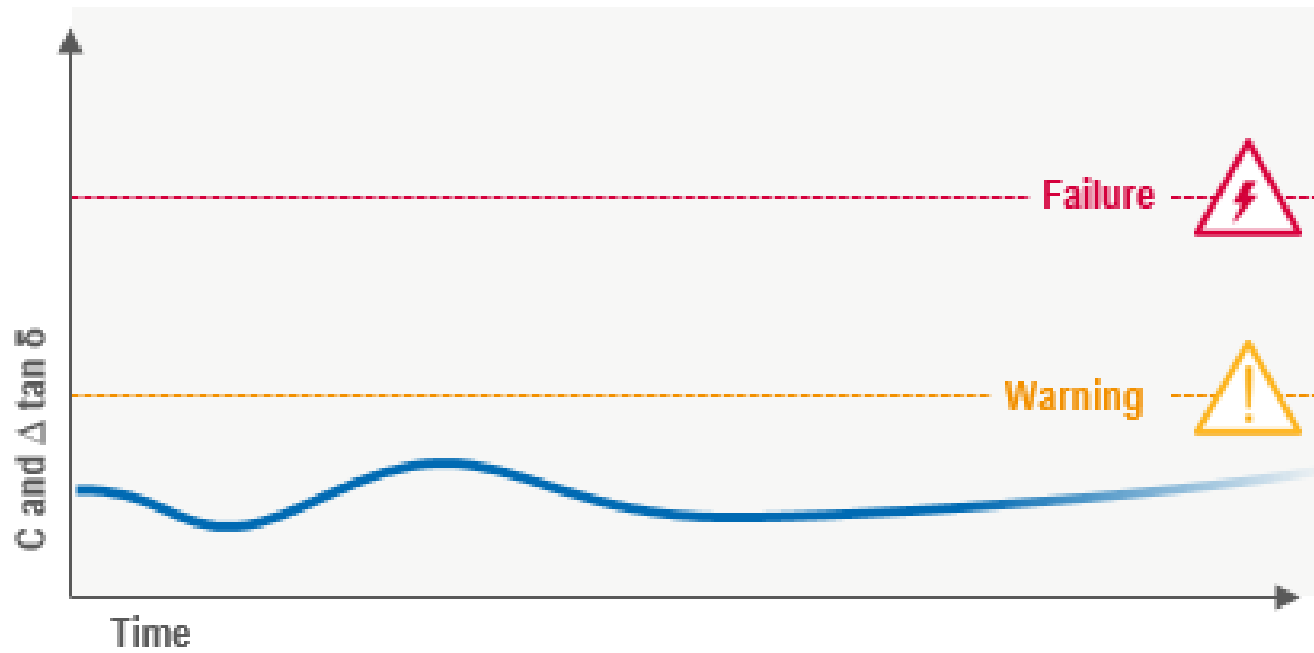
- ❑ Eliminates environmental influences (e.g., weather conditions)
- ❑ Eliminates influence of operating conditions
- ❑ No additional sensors → no possible source of errors

C and $\Delta \tan \delta$
comparison (L1-L2 / L2-L3 / L3-L1)



Online Bushing Monitoring

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- ❑ Limit values can be configured
- ❑ Warning if the limit value is exceeded by 5%
→ Check and take measures to prevent failure
- ❑ Alarm if the limit value is exceeded by 10%
→ Shutoff, operation is risky



Online Dissolved Gas Analysis (DGA)

IEC 60599



- | “Dissolved and free gas analysis (DGA) is one of the most widely used diagnostic tools for detecting and evaluating faults in electrical equipment filled with insulating liquid.”
- | “**On-line gas monitors** ... may be particularly well-suited for **detecting non-typical rates of gas increase** occurring within minutes, hours or weeks, **which is generally not possible with routine oil samplings** done at monthly or **yearly intervals.**”



Online Dissolved Gas Analysis (DGA)

30 ppm is a critical value
for moisture in the oil



Online Dissolved Gas Analysis (DGA)

Warns and notifies the user when an individually defined limit value is exceeded

MSENSE DGA 23



Online Dissolved Gas Analysis (DGA)

Online DGA

DGA 1 - 8 gases

Moisture



Interval 6x day



Continuous Trend

Oil Laboratory

DGA 11 gases

Moisture



Breakdown voltage

Interfacial tension

Color index

Acidity

Sediment, sludge

Particles

... and much more



Interval 1x year



Single Snapshot



Background

| Thermal faults

| Oil decomposition

- | H₂, CH₄ - at low temperatures
- | C₂H₆, C₂H₄ - additionally at high temperatures

| Cellulose decomposition

- | CO, CO₂

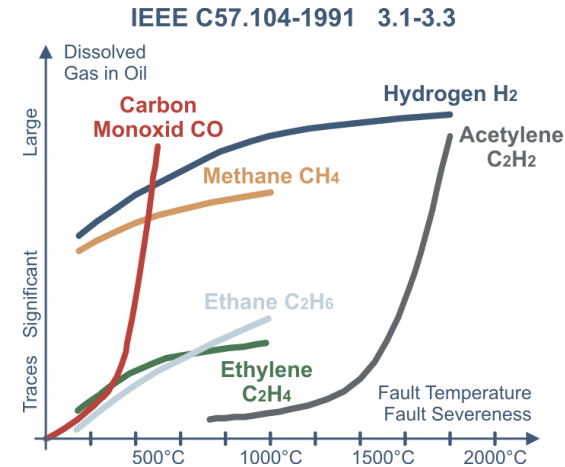
| Electrical faults

| Low intensity discharges

- | H₂, CH₄ - low intensity
- | C₂H₂, CH₄ - additionally at high intensity

| High intensity arcing

- | C₂H₂ - large quantity



Presence of
H₂ / CO → Alarm Signal
C_xH_x → Fault Classification



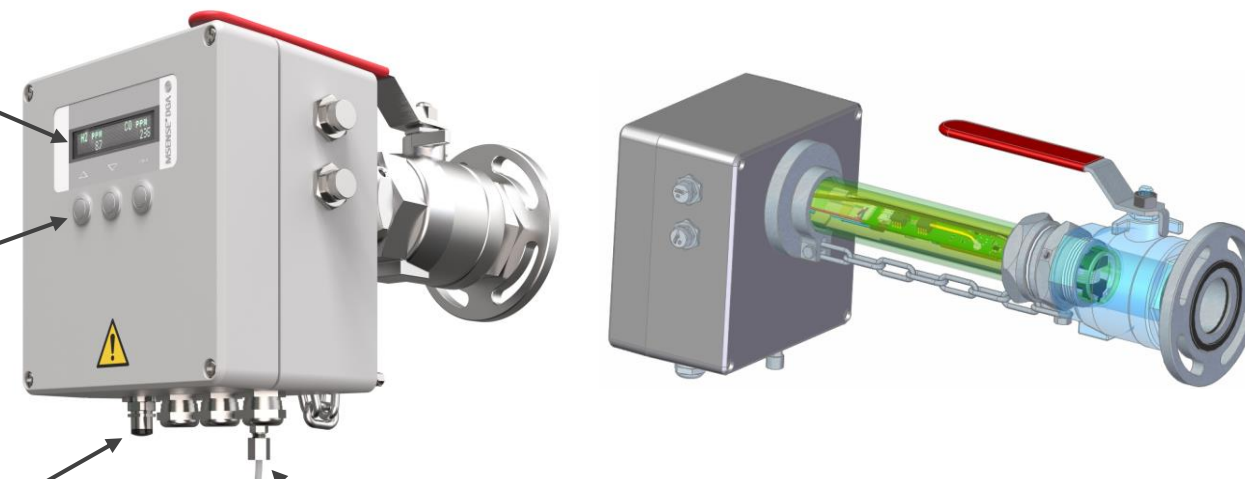
Online Dissolved Gas Analysis (DGA)

Integrated display* with alternating display of measured values, warnings and alarms

Retrieval of parameters and limit values using three operating keys *

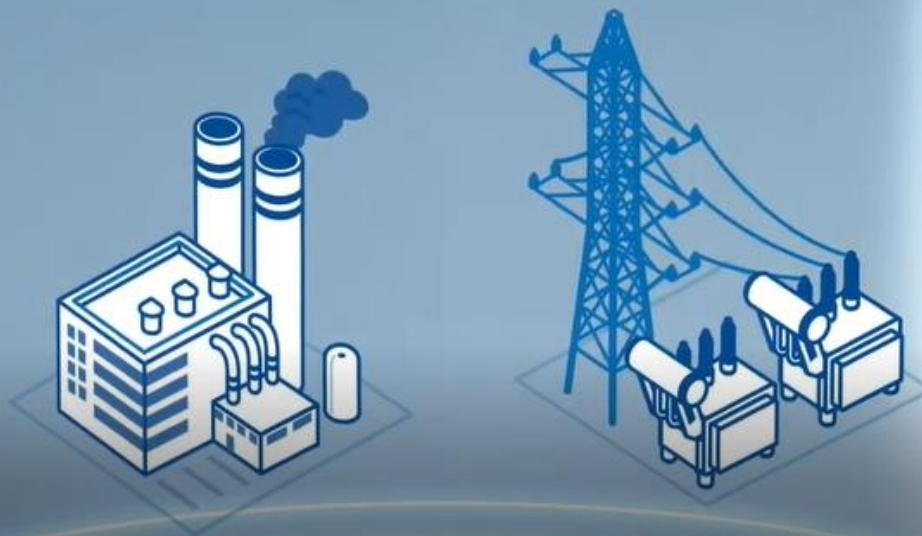
Easy integration into the ETOS® Embedded Transformer Operating System from MR or to SCADA

Standardized adapter for easy oil sampling for a lab analysis



Online Dissolved Gas Analysis (DGA)

For strategically
important transformers



MSSENSE DGA 59



Online Dissolved Gas Analysis (DGA)

Dissolved gas analysis (DGA)

- | Hydrogen H_2
- | Carbon Monoxide CO
- | Acetylene C_2H_2
- | Ethylene C_2H_4
- | Dissolved moisture analysis
- | **Infrared** gas sensor unit for CO, C_2H_2 and C_2H_4



Online Dissolved Gas Analysis (DGA)

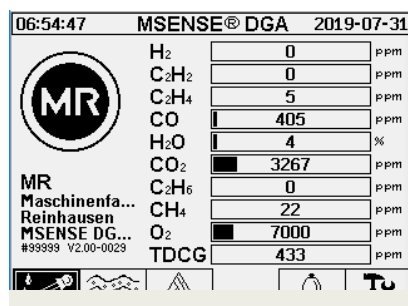
Dissolved gas analysis (DGA)

- | Hydrogen H_2
- | Carbon Monoxide CO
- | Carbon Dioxide CO_2
- | Acetylene C_2H_2
- | Ethylene C_2H_4
- | Methane CH_4
- | Ethane C_2H_6
- | Oxygen O_2
- | Dissolved moisture analysis
- | **Infrared** gas sensor unit for CO , CO_2 , C_2H_2 , C_2H_4 , CH_4 and C_2H_6

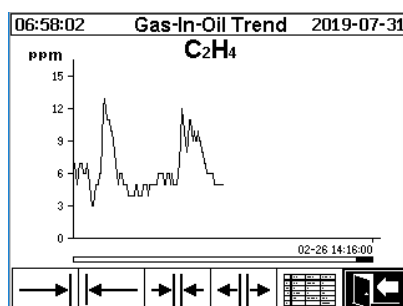


Online Dissolved Gas Analysis (DGA)

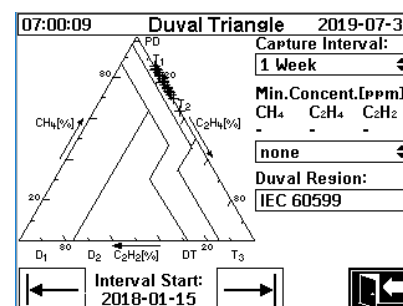
MSENSE® DGA Screens



Main Screen with current gas values & diagram and communication of values via analog outputs and protocols



Gas in oil graph view for trend analysis



Duval Triangle view

¹⁾ MSENSE® DGA 9 only



Fiber Optic Online Temperature Measurement

Increasing hot spot temperature dramatically reduces transformer lifetime

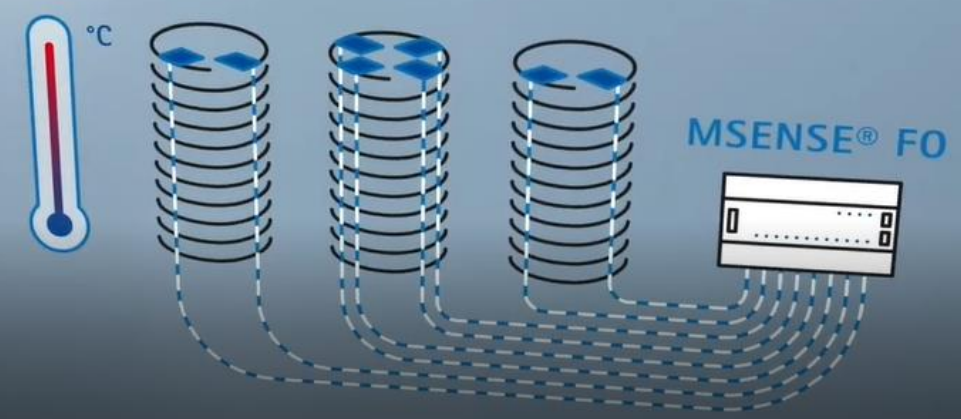


An increase of 12°C in hot spot temperature costs 75% of total transformer lifetime!



Fiber Optic Online Temperature Measurement

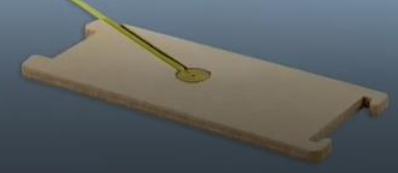
Accurate depiction of the winding temperature continuously in real time



MSENSE® FO

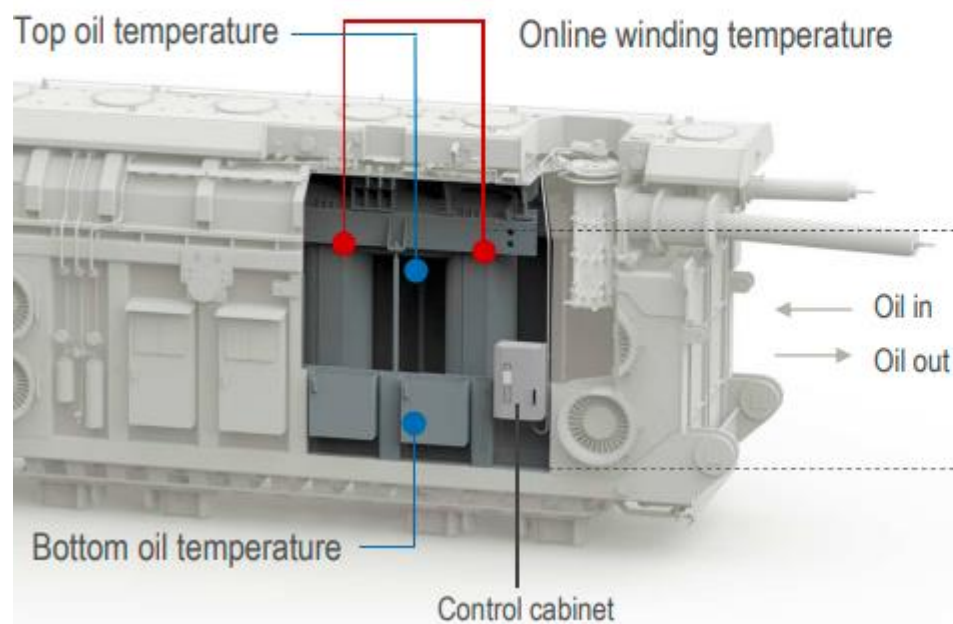


Continuous measured value monitoring of up to 32 sensors and transmission via fiber optics to the MSENSE® FO evaluation unit

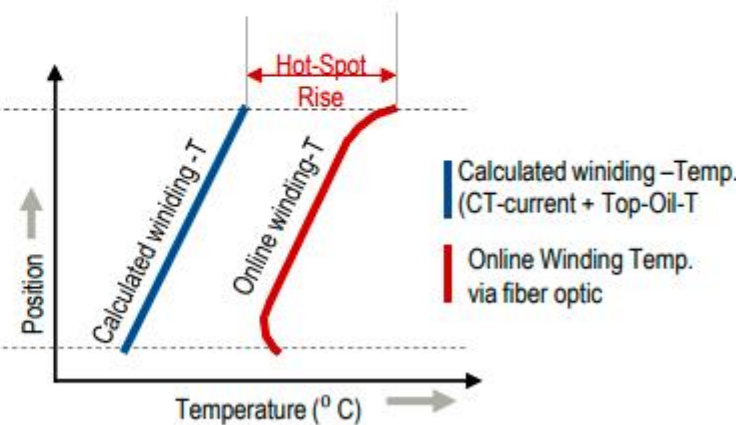


Fiber Optic Online Temperature Measurement

Online winding temperature is more precise than calculated winding temperature.



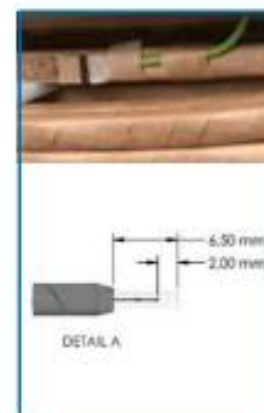
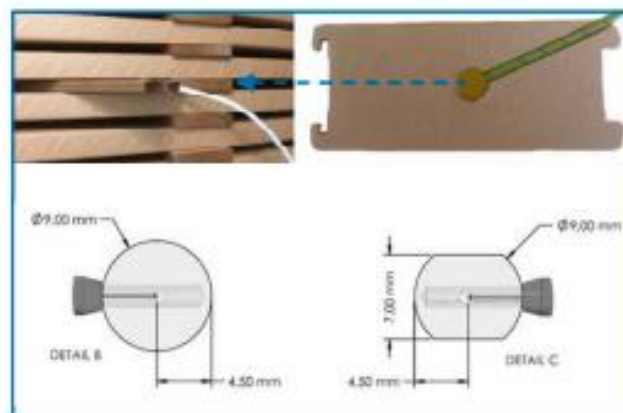
Conventional heat run tests
do **NOT** reveal hot spots!



Fiber Optic Online Temperature Measurement

Technical features

- | Measuring range: - 80°C to 200°C
- | Resolution 0,1°C, Accuracy ± 1 °C
- | Length: 4, 8 or 12m
- | Possible to install in any way



Tap Changer Monitoring

MSENSE® VAM



Tap Changer Monitoring



Tap Changer Monitoring

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Tap Changer Monitoring

Vibroacoustic sensor

| On OLTC head cover, robust, with kick protection

ETOS® IM modules

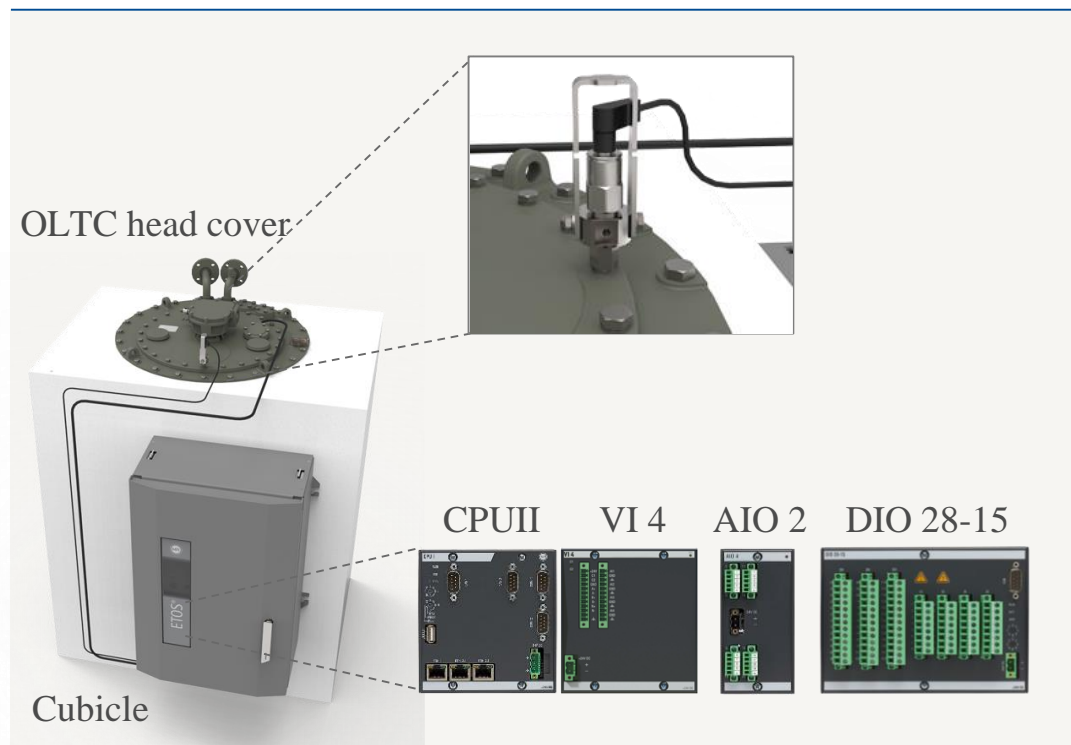
| CPU II: Central processing unit with all communication interfaces, including to the control center and web visualization

| VI 4: Assembly for measuring the vibroacoustic signals of the OLTC

| AIO 2: Temperature acquisition

| DIO 28-15: Digital input/output module (relay outputs)

For 1- & 3-column applications possible



Tap Changer Monitoring

Signal recording: Vibroacoustic sensor

Vibroacoustic Signal

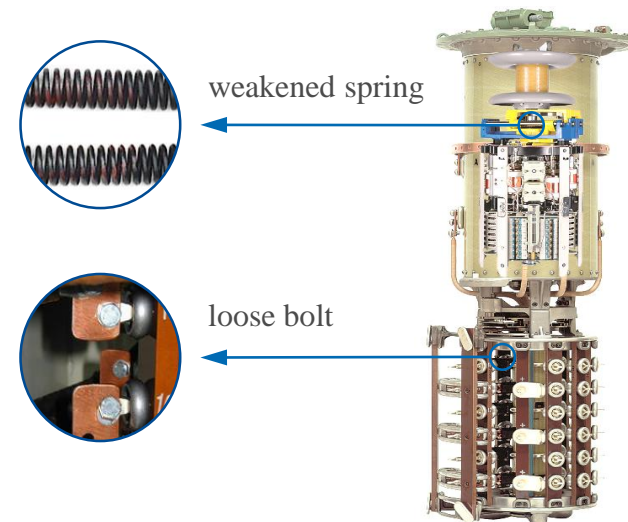
- | Recording during the switching process plus 2 sec before / after to detect the background noise
- | Sampling rate ~ 50 kHz in the frequency range 10-20 kHz



Tap Changer Monitoring

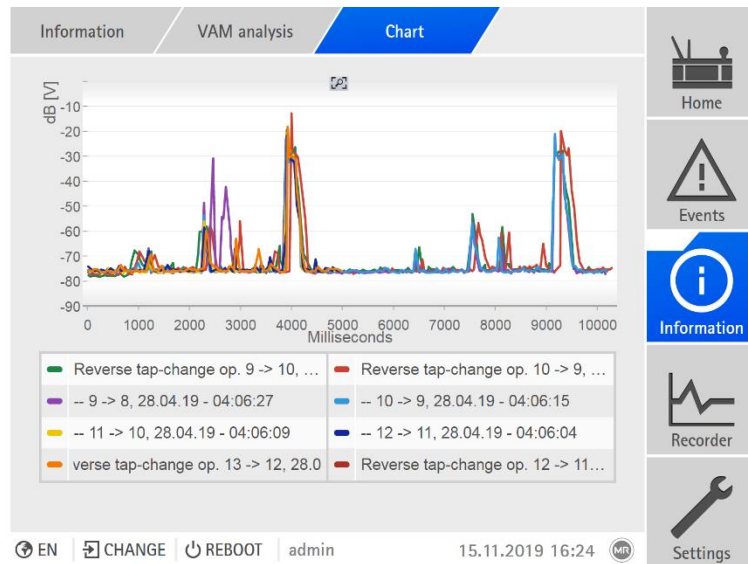
Problems that MR can detect during a detailed analysis

- | Mechanical irregularities in the tap-changer such as ageing and weakening of springs
- | Time differences in the switching process compared to the reference recordings
- | Malfunctions of the motor drive functions such as synchronization problems



Tap Changer Monitoring

Signal evaluation: calculation and visualization of the envelope curve per switching operation

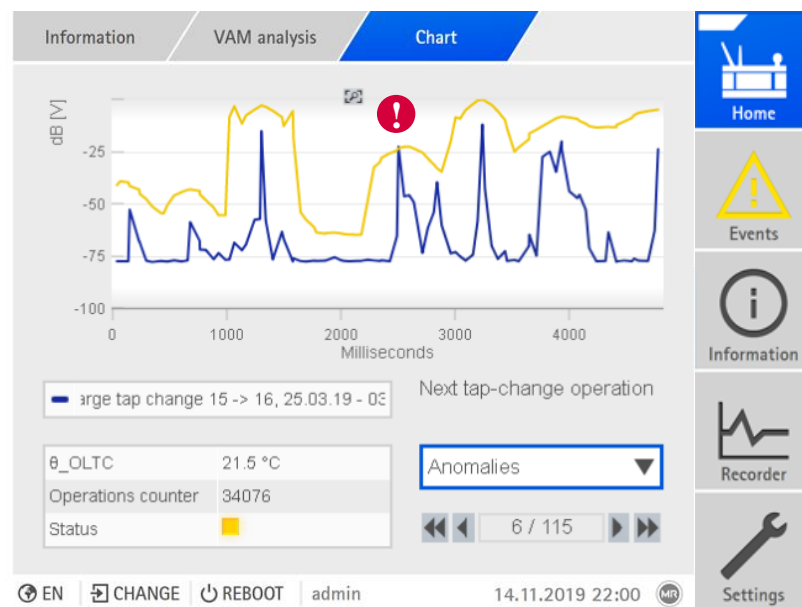


Envelope curves for different switching cluster (per colour)

- | Learning phase approx. 10 switching operations per switching cluster, usually learned after 1 to max. 2 days
- | Continuously narrowing tolerance band

Tap Changer Monitoring

Event message when limit value is exceeded

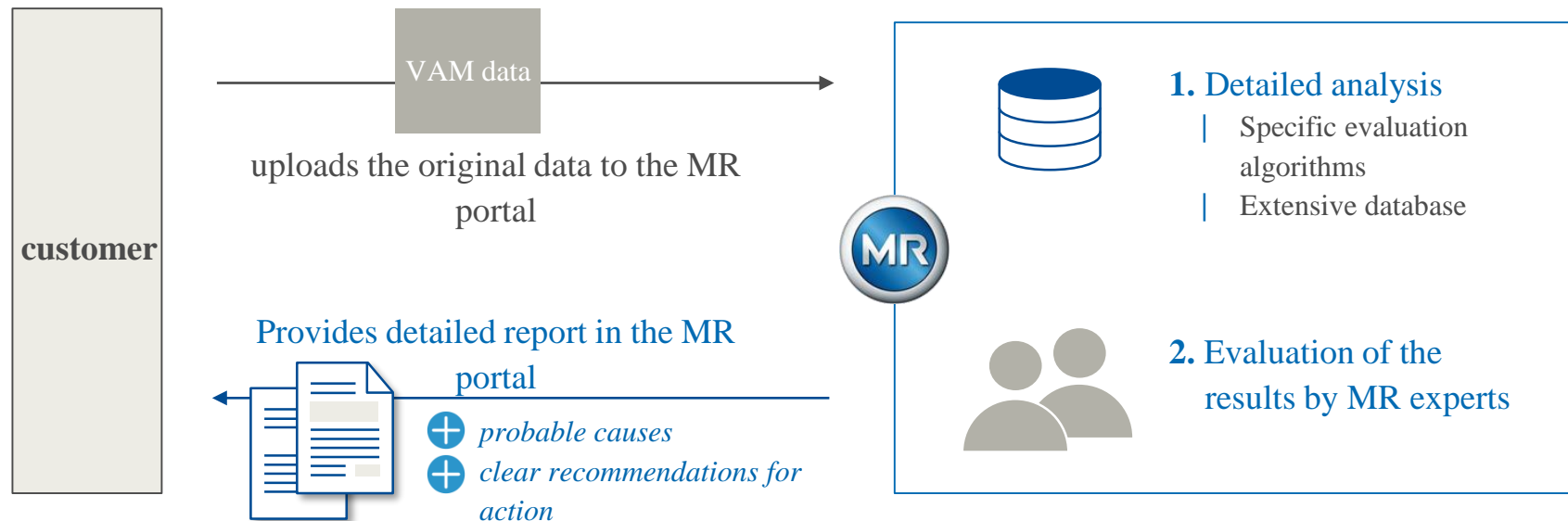


— Limit value curve — Envelope Curve



Tap Changer Monitoring

VAM ANALYSIS SERVICE: Cause analysis & recommendations for action by MR

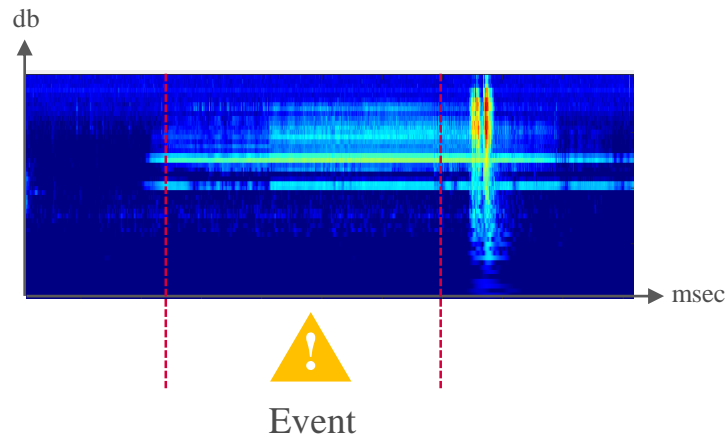


Tap Changer Monitoring

Detailed analysis by MR

3 VAM ANALYSIS SERVICE: Cause analysis & recommendations for action

Detectable anomaly



Detected error*: Rust on base plate & diverter switch



Silicone Composite Bushing

Critical features/disadvantages of using porcelain bushings:

- ❑ Risk of oil leakage
- ❑ Risk of breakages due to vandalism/fragility
- ❑ Risk of explosion due to electrical arcs
- ❑ Risk to initiate a transformer fire
- ❑ Need of regular maintenance (cleaning & washing)
- ❑ Difficult handling/assembling
- ❑ Not suitable for horizontal mounting
- ❑ Good compression strength but weak bending strength



Silicone Composite Bushing

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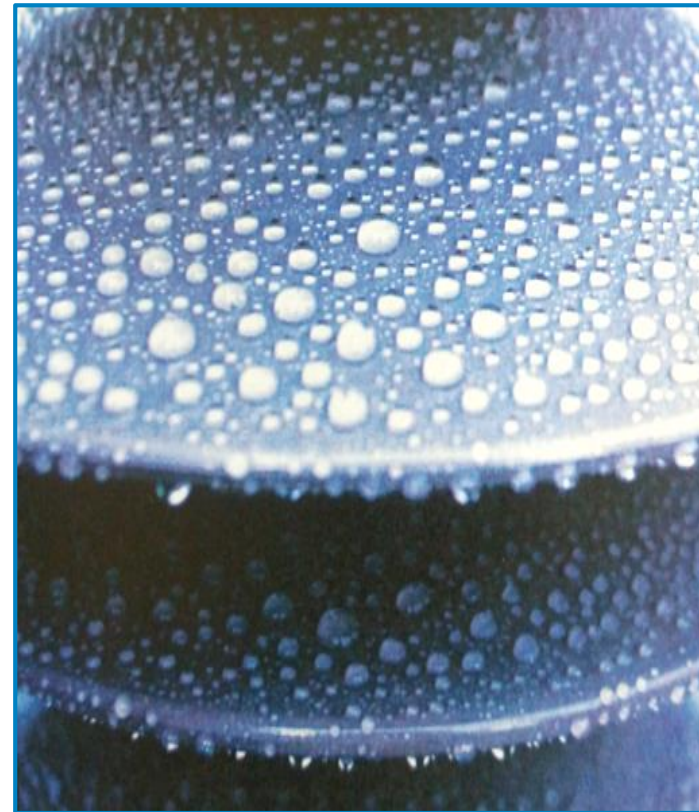
- ❑ A fiber glass tube guarantees superior mechanical strengths to SBC bushings
- ❑ Alternated shed profile from silicone rubber layer molded on the fiber glass tube ensures all electrical features



Silicone Composite Bushing

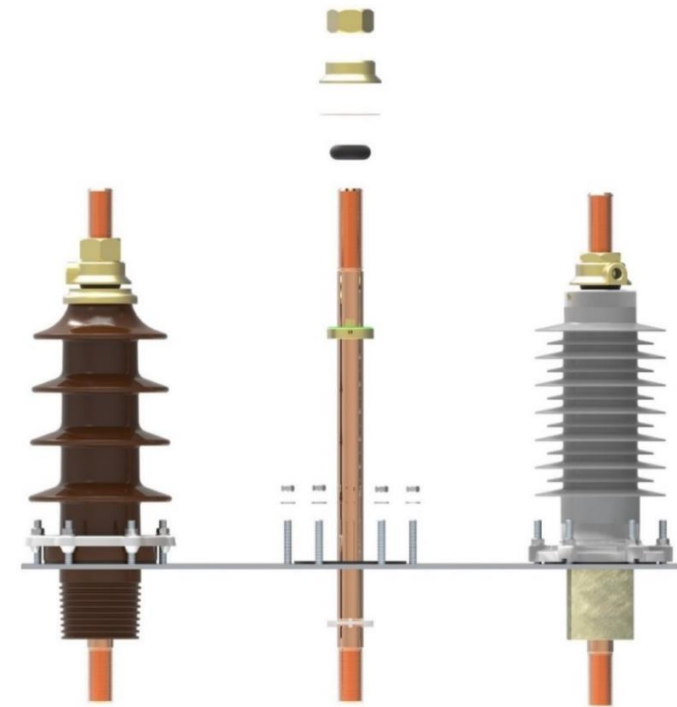
Silicone rubber layer:

- ❑ Self cleaning
- ❑ Hydrophobic
- ❑ Resistant to UV radiation and weathering
- ❑ Elastic
- ❑ Low flammability
- ❑ Temperature stable
- ❑ Very good dielectric properties



Silicone Composite Bushing

- ❑ Perfect **retrofitting** to old porcelain bushing
- ❑ Same **overall dimensions** of the corresponding HV porcelain bushing type (either in accordance with DIN 42533 & 4 or to EN 50180)
- ❑ Greater **creepage distance**
- ❑ Alternated **shed profile**
- ❑ **Anti-fogging** performances optimized by this new design
- ❑ from **-60°C** up to **+140°C**
- ❑ Excellent insulation even **in very polluted environments**



Silicone Composite Bushing

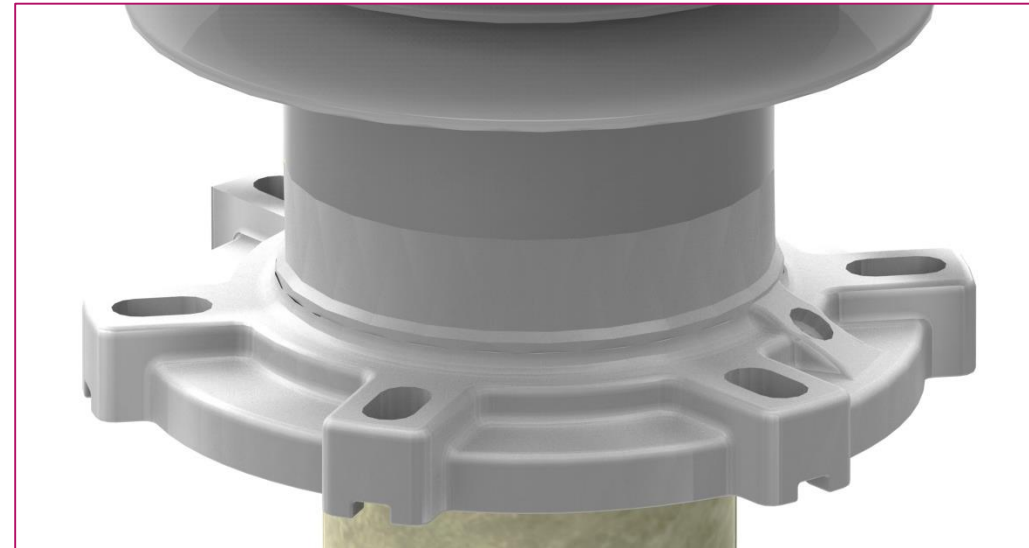
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- ❑ Off-shore execution available
- ❑ Hollow core oil communicating Composite bushing (non capacitance graded)



Silicone Composite Bushing

- ❑ Integrated directly on composite body
- ❑ No need of using clamps for fixing
- ❑ Good resistance to bending loads
- ❑ Manufacturing flexibility
- ❑ Improved strength
- ❑ Reduced risk of oil leakage



Composite Pylon

- ❑ In many areas of the world, the public is increasingly opposing new lines due to:
- ❑ Visual impact
- ❑ Fear of magnetic fields
- ❑ Environmental effects of the towers



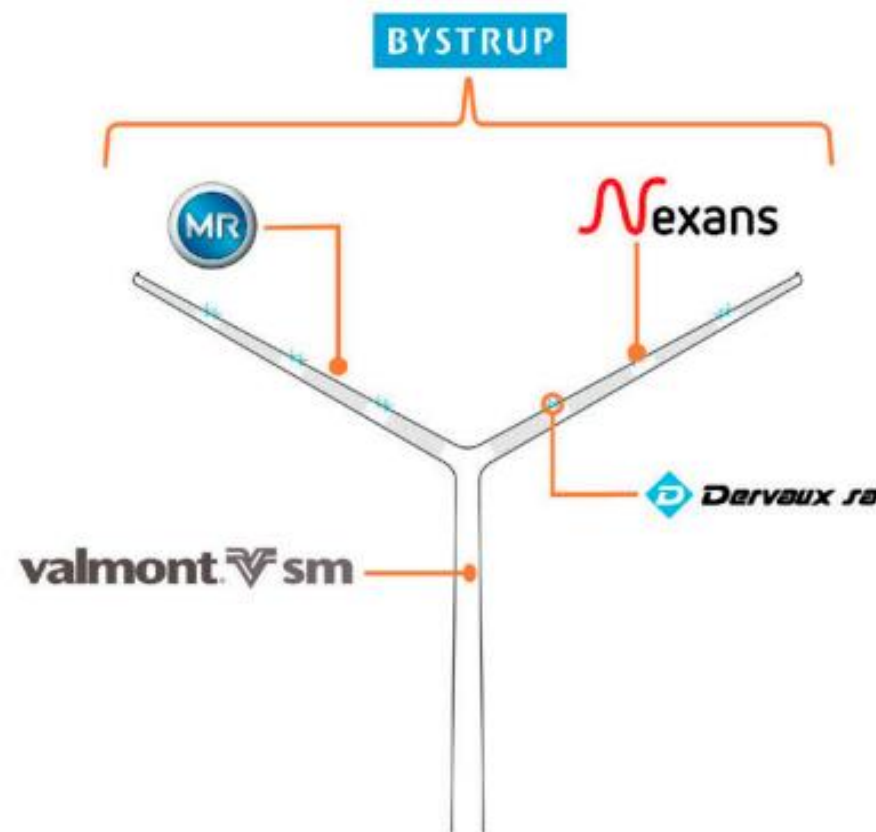
Composite Pylon

- At the same time, operators and utilities are under pressure to **deliver power continuously** and **efficiently** at a **low cost** and to **minimize the effects on the environment**

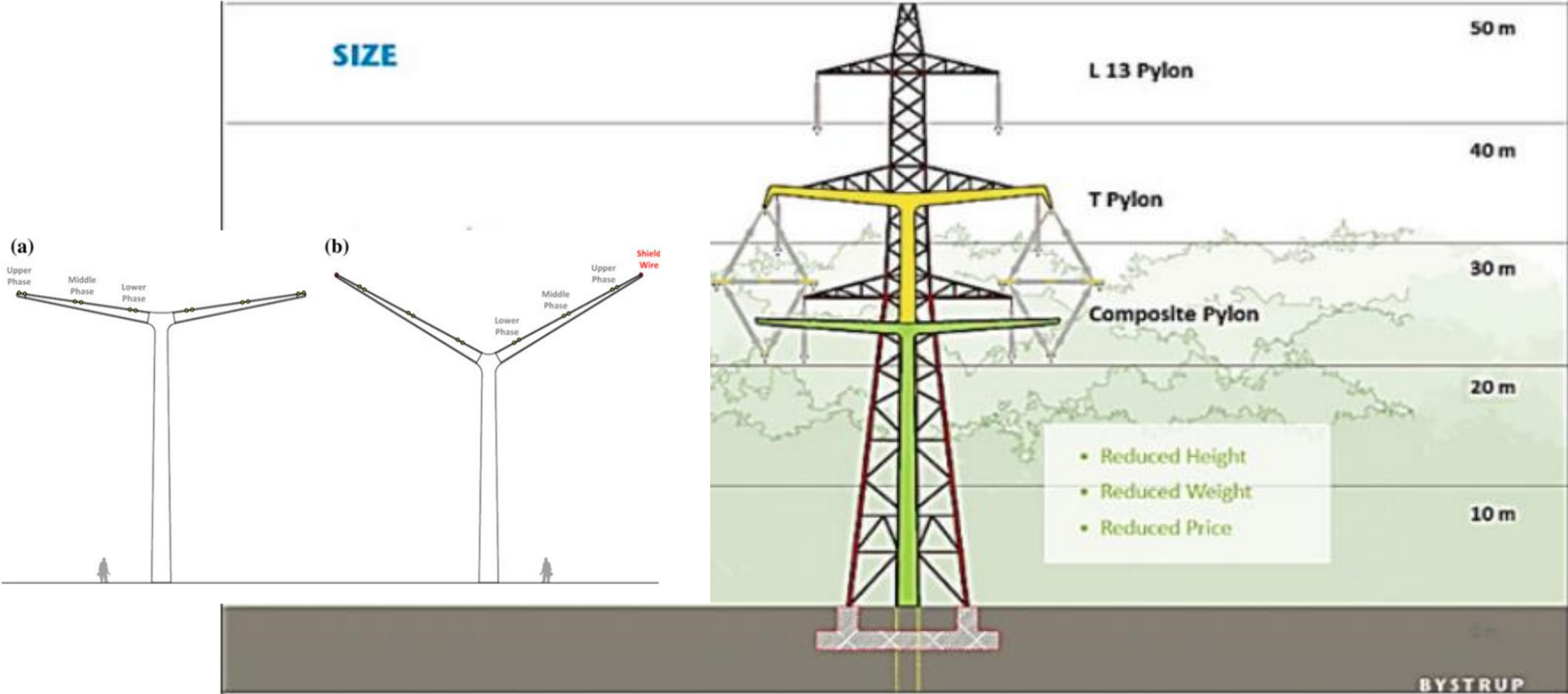


Composite Pylon

- ❑ Designer: **BYSTRUP ARCHITECTS AND DESIGNERS** (Denmark, www.powerpylons.com)
- ❑ Composite Producer: **Reinhausen Power Composites** (Germany, www.reinhausen.com)
- ❑ Construction: **VALMONT SM** (Denmark, www.valmontsm.com)
- ❑ Conductors: **NEXANS** (France, www.nexans.com)
- ❑ Fittings: **DERVAUX SA – SICAME Group** (France, www.sicame.com)



Composite Pylon



Thank you for Your Attention




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