INTRODUCTION TO TRANSFORMER EMBEDED OPERATING SYSTEM (ETOS)

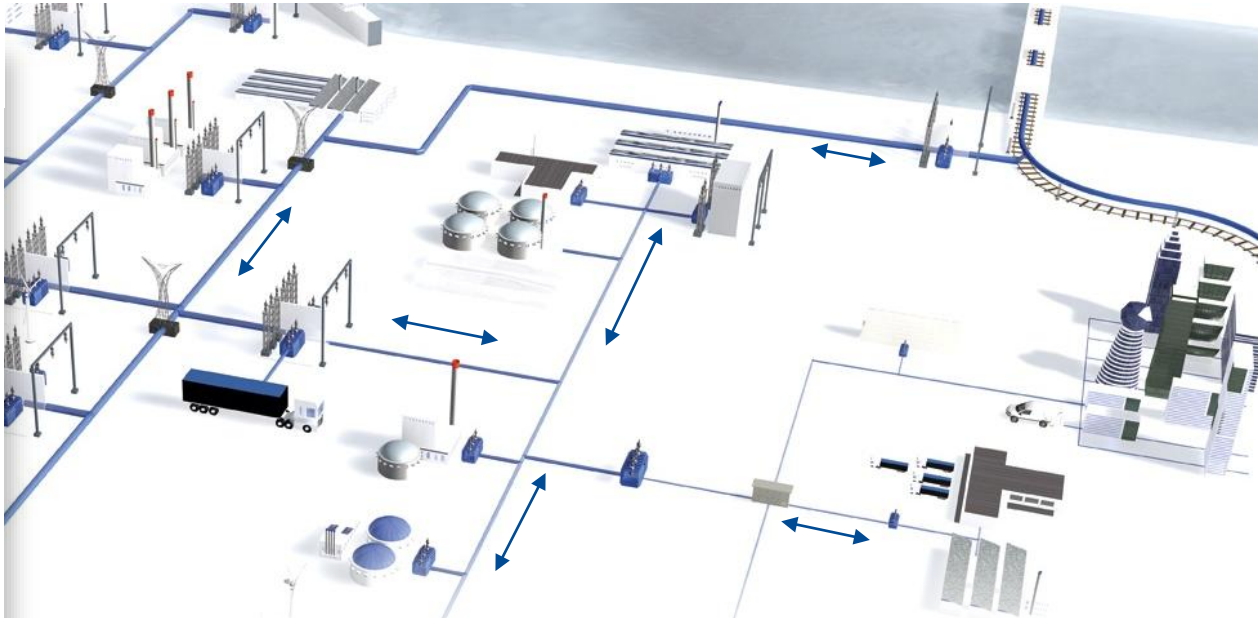
Dr. Pedram Elhaminia

DRAMATIC CHANGES IN THE T&D ENVIRONMENT

Decarbonization

↓ CO_2

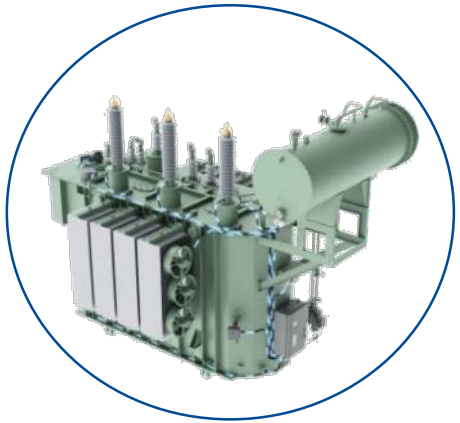
Decentralization

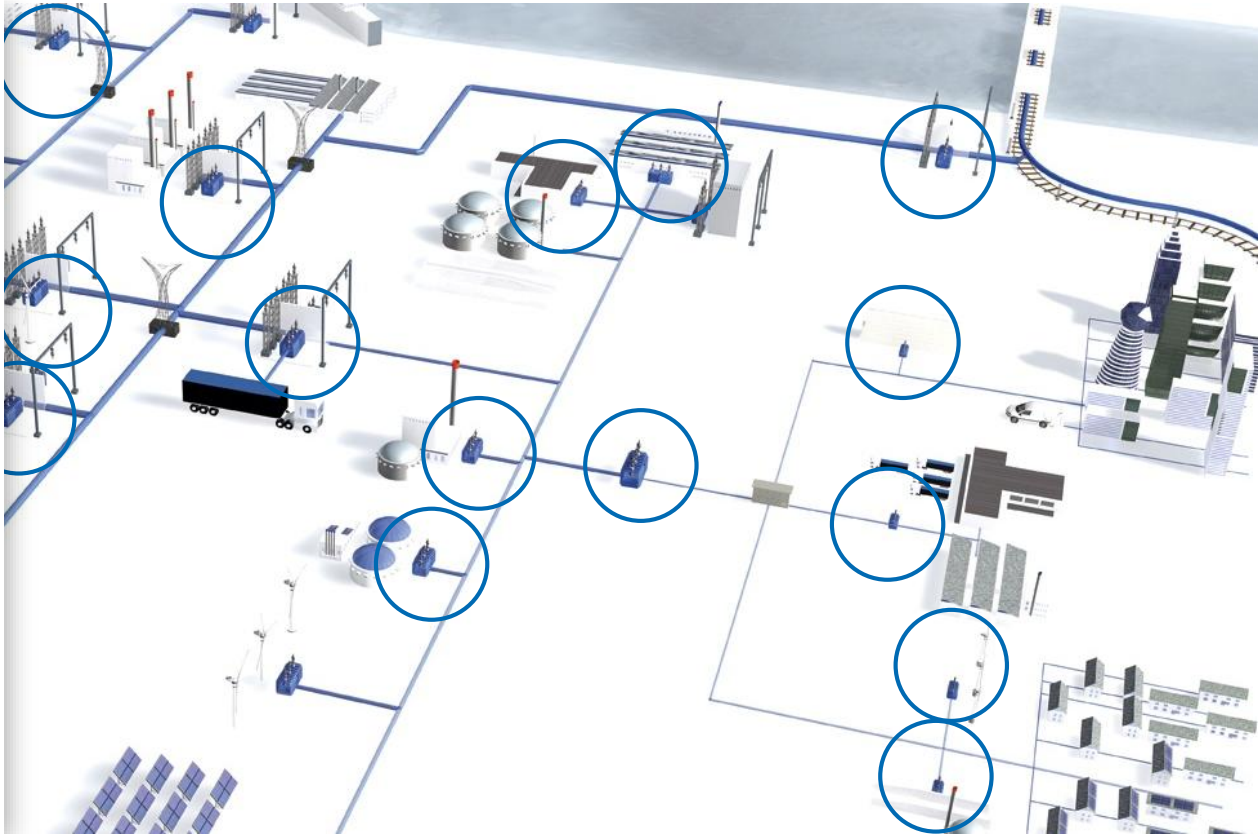


From centralized power-generation & unidirectional grid-utilisation
to decentral and distributed energy systems & multidirectional balancing

TRANSFORMER: CENTRAL NODE & ASSET

Most of the actual challanges pointing to transformers





TRANSFORMER

Operation complexity perspective

- Transformer as a grid node per se
- Grid node must-haves are flexibility, overload capability and contribution to grid stability

Asset criticality perspective

- Most valuable single asset in the T&D system
- Critical replacement-time and -effort
- Average fleet age > 40 years in mature T&D-environment

Transformer attributes & abilities are mission critical in the new T&D environment

ENERGY T&D ECOSYSTEM

Energy admin & regulator

Grid operators & asset managers

Transformer Manufacturers

Enablers & component suppliers

Decarbonization

Energy management requirements

Transformer ability requirements

Component and subsystem requirements

Vertically connected

Common agenda

DRIVEN BY

Decarbonization

Decentralisation

Volatility

Complexity

Uncertainty

GRID OPERATOR

Master volatility

- Switching off / redispatch is no option
- Asset overload capability is mandatory
- Get input to support decision making and system stability

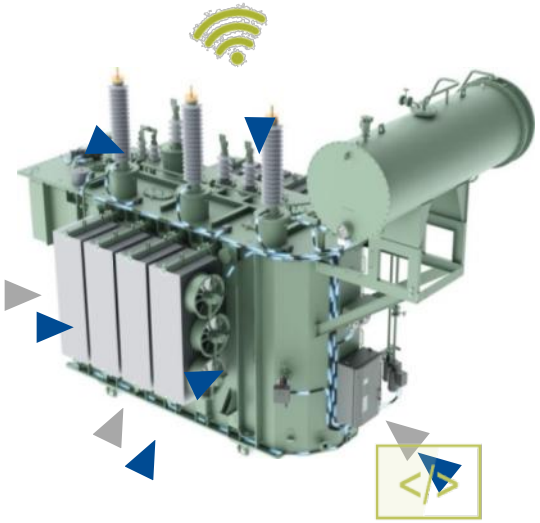
Manage threats, recover fast

- Prevent hazards & cybercrime
- Master abnormal conditions

Optimize asset utilization

- Manage fleet and assets based on state and risk estimation
- Link asset lifetime consumption with decision making for grid operation

TRANSFORMER MANUFACTURER



Cloud and / or edge
Variety of makes, standards, protocols

- Data collection, interpretation, storage
- Visualization

Monitoring, control, regulation functions
Variety of makes, standards, protocols

- Transformer monitoring
- Dissolved gas analysis (DGA)
- OLTC monitoring
- Bushing monitoring
- Voltage regulation
- Cooling fan & pumps

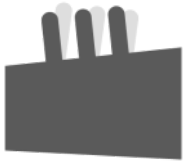
Intelligent sensors and accessories
Variety of makes, standards, protocols

Control cabinet pain points

- Specification conformity
- Specification variety
- Order change management
- Engineering (elect., mech.)
- Cabinet (IP xy)
- Panel interior (terminals, relays..)
- Wiring (inside & from/ to cabinet)
- Makings, codings, colors
- Testing
- Make-, buy-logistics

Challange: transformer control cabinets and marshalling boxes

TRANSFORMER MANUFACTURER



Optimize value chain

- Reduce complexity & cost
- Improve $/MVA -competitiveness

Gain a competitive edge

- Provide resilience and support fast disaster recovery
- Provide overload capability

Meet digital demands

- Offer customized solutions for data-driven grid & asset management

COMPONENT SUPPLIERS

Primary components:

- OLTCs
- Insulation (solid & liquid)
- Winding
- Bushings

Secondary functions:

- Transformer monitoring
- Dissolved gas analysis (DGA)
- OLTC monitoring
- Bushing monitoring
- Voltage regulation
- Cooling fans & pumps

Sensors and accessories

Pain points

- Primary arena driven by price & feature dumping rather than complexity reduction & digital enabling
- No visible focus in the secondary arena: broad spectrum of disintegrated secondary functions, sensors and accessories ranging from simple measuring devices to high-end analytical systems
- No or unsafe link to next level data and communication
- No opportunity to offer added value by upstream integration or smart cross-level solutions

Challange supplier integration: safe data interface and open protocols needed

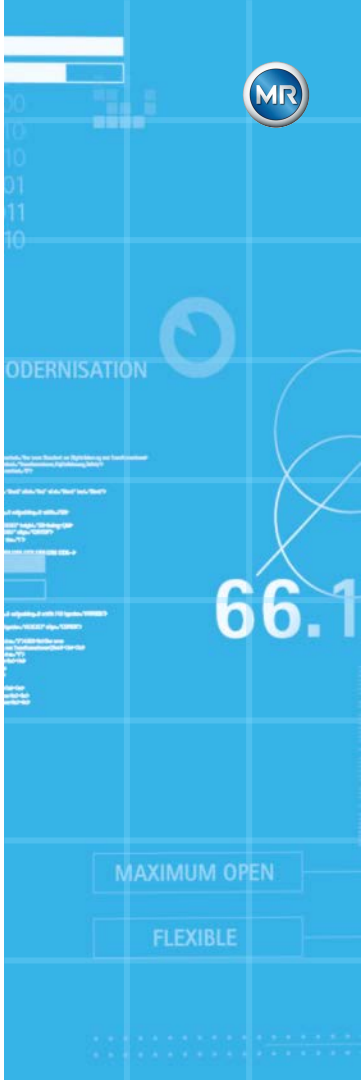
COMPONENT SUPPLIERS

Integrate seamlessly

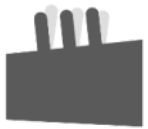
- Connect via central communication interface and standard protocols

Create new business models

- Access fully open data interface
- Develop digital expert solutions, e.g. OEM-specific thermal transformer modeling or gas-in oil expert system



WHAT IF...



Energy admin & regulator

Grid operators & asset managers

Transformer OEMs

Enablers & component suppliers

Master volatility, recover fast, optimize asset utilization

Facilitate intelligent grid operation and asset management

Integrate seamlessly, create new business models

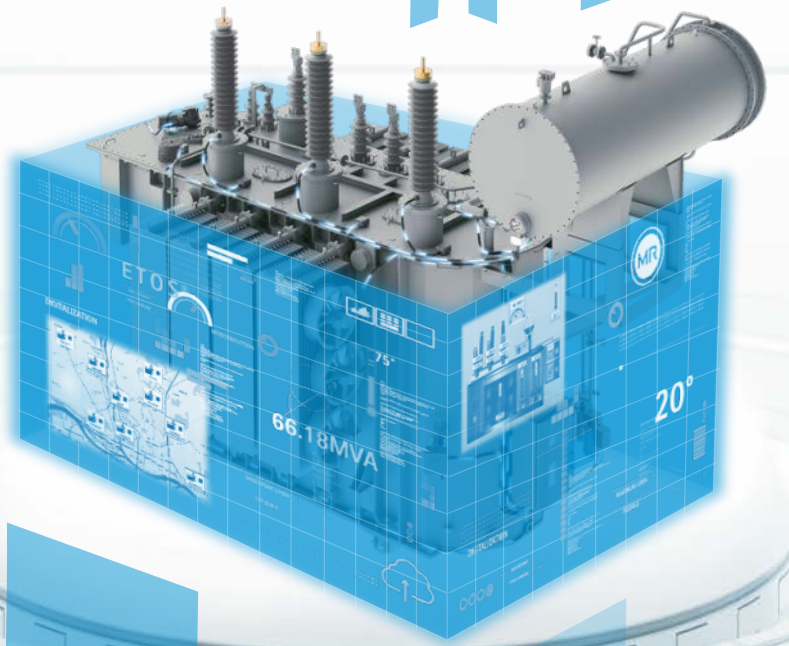
SOMEONE HAD

A VERTICAL INTELLIGENT,

ENABLER?

ETOS®

Intelligent
Enabler



Embedded
Transformer
Operating
System

What makes an operating system?

User interface

Data storage

Data exchange

Applications

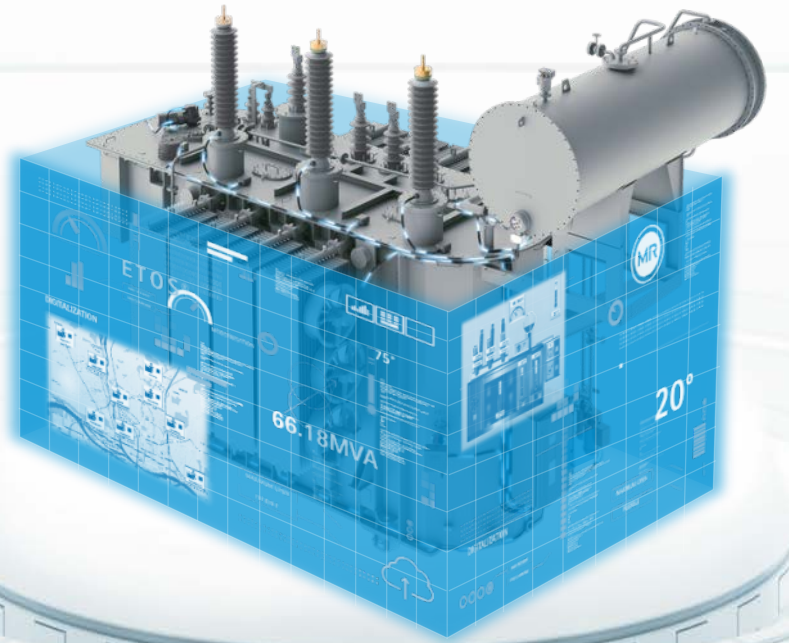
Communication

Hardware

Software

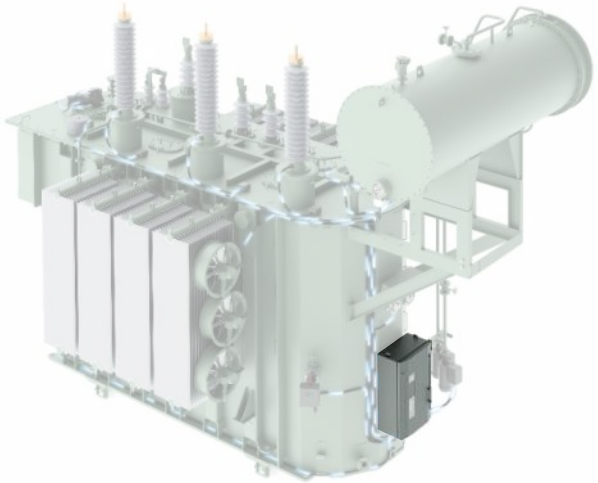
ETOS®

Enabling all players



Embedded Transformer Operating System

A Modular Solution



Modular ETOS® designs

ETOS® cabinet options
rugged „home“

ETOS® IM
intelligence put in rugged hardware

Modular ETOS® applications

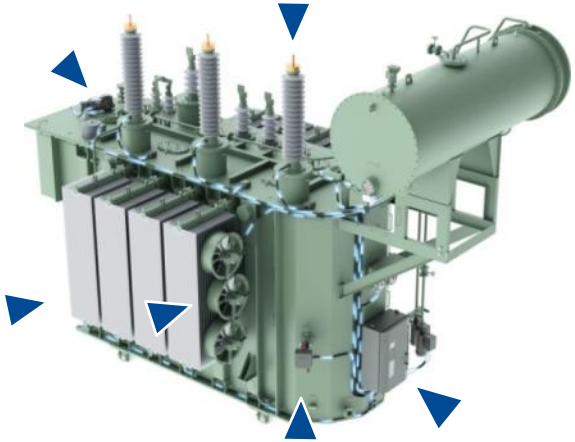
Monitoring

Control & Regulation

Additional functions: visualization & communication

MONITOR & CONTROL

Smarter



Monitoring

Control

Available ETOS® applications

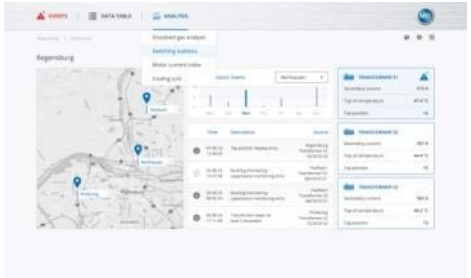
- Transformer
- Dissolved gas analysis (DGA)
- Tap-Changer (OLTC)
- Bushings

- Voltage regulation
- Cooling fan & pumps

KNOW THE STATUS

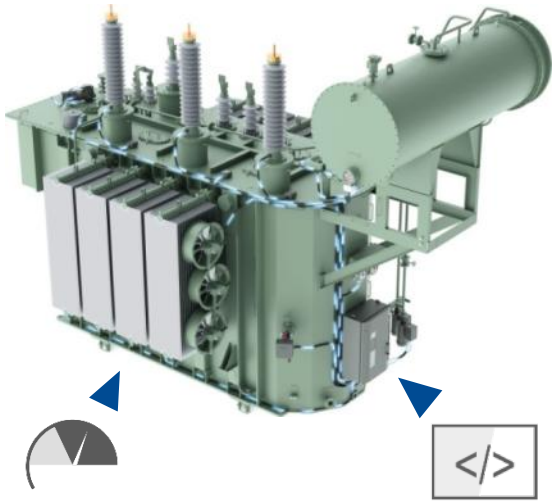
Anytime & Anywhere

- No-frills web-browser visualization
- Intuitive user-interface
- Simple integration of whole asset fleet in a central browser application



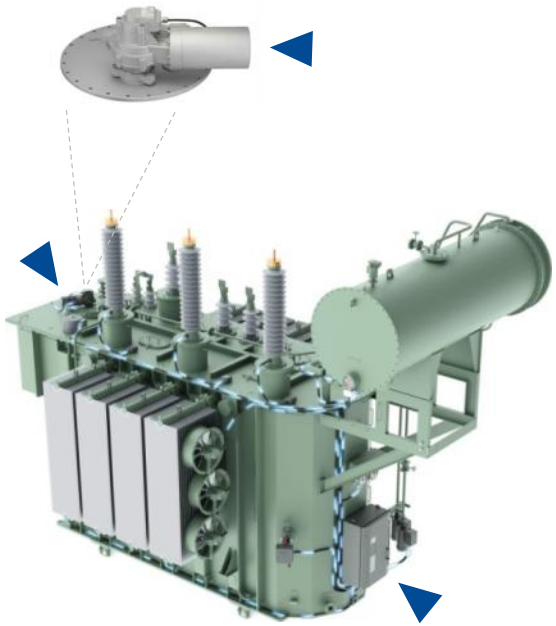
TAILOR & AUGMENT

Easily



- Customize transformer design and function using our flexible modules
- Integrate your own hard- and software using open protocols, up- & downstream
- Develop custom program extensions using TPLE function
- Create new digital business opportunities

LEVERAGE SYNERGIES



from Integration

- Eliminate separate cabinets and housings
- Eliminate mechanical drive shaft through optional innovative top drive
- Save working hours, gain space
- Reduce interfaces, connect easier
- Save copper cables, use glas fibre

ZERO System-Cost Impact

For Transformer Manufacturers

Save Costs and Time by Integration

Voltage regulation

Integration in ETOS® cabinet
instead of separate device

up to
65%

Transformer & DGA Monitoring

Integration in ETOS® cabinet
instead of separate device

up to
75%

Substation SCADA wiring

Via glasfiber
instead of copper cables

up to
70%

Installation of top drive

Instead of drive with
mechanical drive shaft

up to
50 h

CYBERSECURITY:

A Certainty

- State-of-the-art standards, audited according to BDEW
- Security-focused product architecture
- Proactive security management by CERT team
- Full data control thanks EDGE, cloud is an option, not mandatory

RBAC
BSI TR 02102
Firewall
Encryption
IEC 62
IEC 62351
Need-to-know
Defense in depth

ETOS® ENABLES

Smart, Integrated Systems

Support data based asset manament and flexible grid operation

Monitor & control individual transformers

Measure & control individual parameters

CONTROL LEVEL

Cloud

SCADA

TESSA®

FIELD LEVEL

ETOS® designs

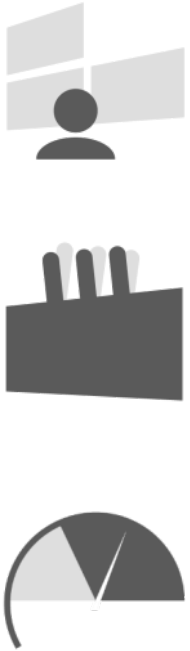
ETOS® applications

PROCESS LEVEL

MR smart & conventional sensors

3rd party devices

ECOSYSTEM



Enabler

- Master volatility
- Maximize asset value

- Streamline your value chain
- Offer highly differentiatd digital solutions at zero system-cost impact

- Integrate any device and app easily
- Create new data-based business opportunities

MR PORTFOLIO FOR TRANSFORMER DIGITALIZATION

CONTROL LEVEL

FIELD LEVEL

PROCESS LEVEL

Cloud

SCADA

TESSA®

ETOS® Designs

ETOS®

ETOS® TD/ ED

ETOS® IM

ETOS® Applications

Monitoring

Control & Regulation

MESSKO®

Conventional Sensors

MSENSE®

Intelligent Sensors

MESSKO®

Protective Devices / Accessories

3rd Party Devices

ETOS® MODULES: DESIGNS & APPLICATIONS

FIELD LEVEL

ETOS® Designs

ETOS®

Standalone variant in the control cabinet

ETOS® ED / TD

Integration solution in the motor-drive unit

ETOS® IM

Solution for integration in a customer control cabinet

ETOS® Applications

Monitoring

- Transformer
- Dissolved gas analysis (DGA)
- Bushing
- Tap-Changer (OLTC)

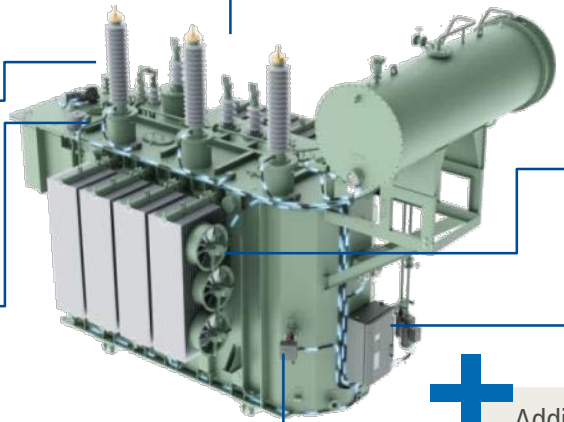
Control & Regulation

- Voltage regulation
- Cooling fan & pumps

ETOS® applications: fully configurable

Monitoring

- Transformer monitoring
- Bushing monitoring*
- OLTC monitoring*
- Dissolved Gas Analysis (DGA)*



Regulation / Control

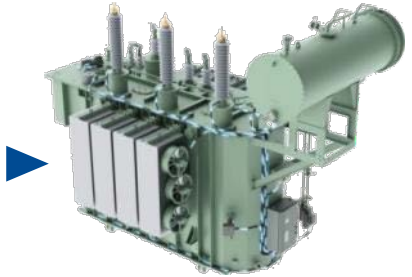
- Cooling system control and monitoring*
- Voltage regulation*

Additional functions
- visualization and communication
- Integration of a standard cooling control cubicle
- Integration of an oil filter unit

* Optional application

FIELD LEVEL

Transformer monitoring



Standard functions (included in each ETOS® scope of supply)

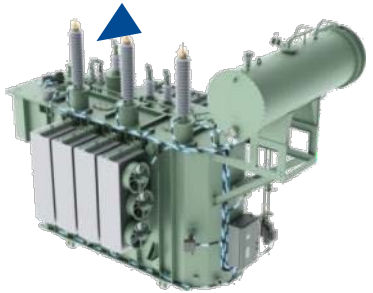
- Status monitoring RS2001, Buchholz relay, PRD, oil filter monitoring
- Monitoring of oil temperature
- System voltage, load current, frequency, load factor, active power, reactive power, apparent power
- Hot-spot calculation in accordance with IEC 60076-7 or ANSI/IEEE C57.91
- Calculation of aging rate and loss-of-life
- Tap position capture

Extended functions

- Capability of transformer to handle overload in the short or long term with live calculation and simulation of overload forecasts in accordance with IEC 60076-7 or ANSI/IEEE C57.91
- Calculation of the bubbling temperature
- Calculation of paper moisture content

Zurück

Bushing monitoring



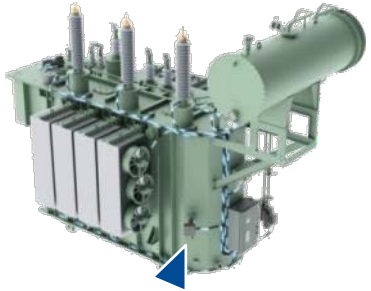
⊕ Functions

- Monitoring of changes in C1 capacitance
- Monitoring of the dissipation factor (tanδ)
- Preset limits for optimal monitoring
- Recording system voltage for effective elimination of network imbalances
- Elimination of temperature influences by using the innovative double-reference method
- For new transformers or retrofit

Continuous status monitoring of bushings

Zurück

Online Dissolved Gas Analysis (DGA)



⊕ Functions

- Online recording of up to nine dissolved gases, relative moisture in oil, and relative overall gas content
- Configurable limit value for each gas
- Curve display of the measured values
- Measured value memory
- Universal 4…20mA or Modbus RTU interface for capturing the DGA sensor signals
- Evaluation in accordance with Duval, Rogers, Dörnenburg, IEC60599

Zurück

OLTC Monitoring

⊕ Basic functions

- Status monitoring of the motor-drive signals
- Maintenance recommendations / maintenance interval calculation for OILTAP® / VACUTAP®
- Calculation of contact wear for OILTAP®
- Tap-position statistics for the OLTC (number of tap-change operations per tap, duration per tap)
- Monitoring of OLTC oil temperature

⊕ Extended functions

- Motor Current Index in accordance with IEEE PC57.143

Zurück

Cooling system control and monitoring

⊕ Intelligent cooling system monitoring

- Number of starts per cooling level
- Operating time per cooling level
- Monitoring of R_{th} and cooling efficiency
- Monitoring of motor protective switches

⊕ Intelligent cooling system control

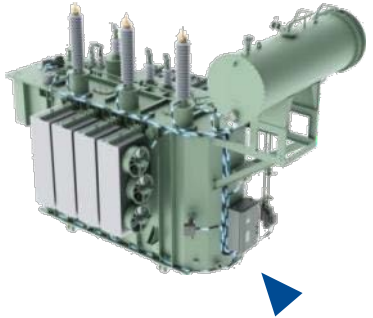
- Switching points, hysteresis and delay times adjustable to your needs
- Various control algorithms
  - Periodic cooling group activation or
  - Predictive cooling
- Fail-safe mode
- Optionally available as frequency-controlled for higher cooling efficiency and less wear of ventilators

⊕ Integration of complete conventional transformer cooling system control

- Including motor protective switches and fuses; for 1, 2 or more cooling stages
- Can be connected to the intelligent cooling control functions such as predictive cooling

Zurück

Automatic voltage regulation



⊕ Basic functions

- Measurement of system voltage and load current (one-phase or three-phase)
- One desired value
- Voltage regulation with linear delay time T1
- Status of the motor-drive unit

⊕ Extended functions

- Various types of desired-value setting (3 or 5 desired values, TAPCON® Dynamic Setpoint Control, desired-value setting via analog value, raise/lower pulse, desired value via BCD)
- Automatic voltage regulation with linear or integral time characteristics and two delay times T1 and T2
- Parallel operation via CAN bus (up to 16 transformers)
- Line-drop compensation (R-X or Z compensation)
- Monitoring of bandwidth
- Function monitoring
- Limit-value monitoring

Zurück

FIELD LEVEL

ETOS®: Stand-alone variant

- Housing made of aluminum sheet, up to IP protection class 66
- Supports passive cooling thanks to its double-walled design
- Corrosion protection class up to CX acc. to ISO 12944-9
- Variable mounting points
- Vibration absorber [1]

- UV-resistant inspection window, information visible from outside [1]

- Integrated laptop holder
- LED cabinet lights

- Display unit with tap position indication [1]
- Mechanical operations counter and status LEDs [1]

- User interface with integrated socket and service interface

- Different cabinet sizes available

[1] Only for some cabinet sizes and variants

ETOS® TD: Innovative On-Load Tap-Changer top drive

Simplified assembly

- No mechanical linkage (drive shafts)
- Fast connection of motor and control cabinet by plug connection
- No manual centering required

Smart functions

- Automatic synchronisation of the on-load tap-changer with the drive
- Electronic end position locking
- OLTC PreCheck function to avoid damage to the tap changer
- Automated monitoring and cost reduction through advanced ISM® technology

Flexibility

- due to modular design, individually expandable

Zurück

ETOS® ED: Intelligence in classic side drive

- Reliable drive of the on-load tap-changer, proven drive technology
- Combined with state-of-the-art automation components
- Many additional functions available for intelligent monitoring, control & regulation of the power transformer
- Double-walled design of the housing supports passive cooling
- Flexibility through modular design, individually expandable

Zurück

ETOS® IM: Rugged automation hardware

Flexible plug-in modules

- The modular and powerful design for tough requirements in energy technology
- Specific modules for each task
- Support of all common interface standards, e. g. IEC61850 protocol
- Operating ambient temperature -25°C to +70°C
- Flexible power supply through wide-range power supplies

- Designed for the harsh ambient conditions directly on the transformer
- Reliable service life of 15-20 years
- Builds on > 40 years of experience with transformer automation

ETOS® IM: Intuitive Software

Individually expandable

- Robust operating system as the basis for all system and application functions
- Database with actual and historical operating data as well as status and log information
- No software installation necessary - cutting-edge, web-based visualization (HTML 5 and SVG)
- Individualization, self-programmable, digital and analog inputs and outputs
- Easy backup of software and configuration (directly on USB or on PC)
- All necessary control station protocols
- Intuitive operation, field tested

CYBERSECURE BY DESIGN

State-of-the-art standard

- External & independent audits in accordance with BDEW*)

Support

- Explicit customer interface for IT security
- Product security management by the CERT team
- Proactive management of security flaws

Product architecture

- Pre-configured, integrated firewall in accordance with IEC 62443
- SSL/TLS (HTTPS) encryption (256-bit) in accordance with BSI TR 02102
- "Role-Based Access Control (RBAC)" role-based user management in accordance with IEC 62351
- Password management in accordance with NERC-CIP
- Defense in depth
- Ability to deactivate hardware interfaces that are not necessary
- Integrity of firmware, software and data

*) Whitepaper: Requirements for Secure Control and Telecommunication Systems, BDEW association Germany

Communication & Visualization

Additonal functions

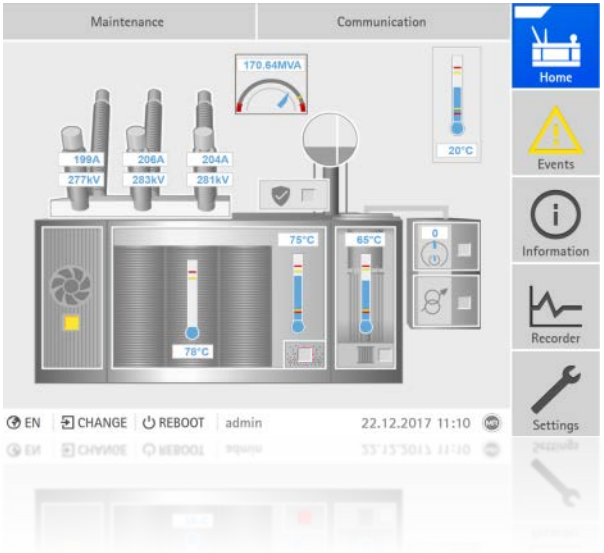
- DIO configuration - freely programmable digital inputs and outputs
- AIO configuration - freely programmable analog inputs and outputs
- TPLE – Program by yourself easily with function blocks

Visualisation

- Visualization via web server (SVG and HTML 5) for various end devices included as standard. No software installation needed.

Communication protocols

IEC61850 Ed. 1 und Ed 2. MMS und GOOSE
IEC60870-5-101, -103, -104
DNP3
Modbus TCP, RTU, ASCII



ETOS® Displays: Fits for every application

- Fast installation plug and play in the station building
- Intuitive graphical menu structure for user-friendly operation
- 19" rack control elements (e.g. switch button "higher" & "lower") are digitally available in the touch panel display
- Connection of up to 10 MR automation products
- Modern web technology, access possible from any device

- Flexible MControl® Touch Panel Display from MR in two versions:
  - Resistive 7" display (top hat rail mounting for integration in motor drive housing or control cabinet)
  - Capacitive 10" display

19“ top-rail mounting display unit

10“ touch display

7“ touch display

MR SOLUTIONS ON THE PROCESS LEVEL: SENSORS & DEVICES

PROCESS LEVEL

MESSKO®

Conventional Sensors

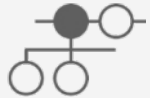
MSENSE®

Intelligent Sensors

MESSKO®

Protective Devices / Accessories

3rd Party Devices



MESSKO®: conventional sensors

Temperature monitoring (for oil and winding)

- MESSKO® COMPACT and TRASY2
  - Bourdon spring technology: very precise and less aging-prone
  - Measurement, displaying, reporting alarms, communication (up to 6 freely adjustable microswitches)

- MESSKO® BeTech
  - Bellows technology, unpressurized fluid
  - optional remote measured value transmission, up to 5 independently adjustable switches (250V/15A) with selectable hysteresis

Level monitoring (for oil)

- MESSKO® MTO
  - Level measurement in oil expansion vessel keeping sensor and display separate
  - Flexible types of the floating unit - radial or axial, 2 or 3 limit switches, adjustable or fixed

- MESSKO® MMK
  - Robust magnetic level indicator without float in the tank
  - Optional limit contacts and remote transmission of measured values, retrofittable to DIN 42 552

MSENSE®: intelligent sensors

Hydrogend, carbon monoxide, moisture level monitoring

MSENSE® DGA

- Detects primary early indicators of thermal and electrical damage
- Extremely precise and independent of environmental influences due to innovative 2-step measuring method

Bushing monitoring

MSENSE® BM

- Innovative, field-tested 2/3 reference method: Monitors the condition in terms of changes in capacitance and dissipation factor
- Eliminates the influence of temperature- and voltage fluctuations

Direct winding temperature monitoring

MESSKO® MTeC EPT303 FO

- Directly measures at the source and communicates the temperatures
- Up to 32 innovative MESSKO® MSpot® – glass-fiber sensors

MESSKO®: Protective devices and accessories

Maintenance-free dehydrating breather

- MESSKO® MTraB®
  - For oil-insulated transformers, reactors and tap changers
  - Sensor controlled regeneration of the drying agent with self-regulating heating element

Protection against critical events

- MESSKO® MSafe®
  - Buchholz relay triggers if gas accumulates or if there is a sudden increase in flow speed, as well as in the event of oil loss

- MR RS2001
  - Relay activates when the specified speed of oil flow between the on-load tap-changer head and oil conservator is exceeded due to a fault. Tried-and-tested thousands of times worldwide

- MESSKO® MFloC®
  - Monitors the flow of coolant in the oil-water cooling, reports pump failure instantly

Pressure relief device

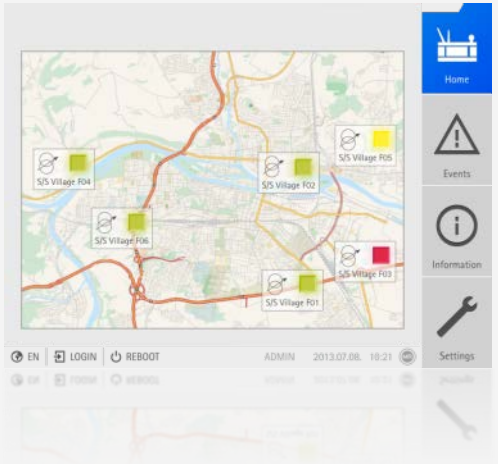
- MESSKO® MPreC®
  - If the permissible valve activation pressure is exceeded, the device opens within milliseconds. Different contact variants available

MR SOLUTIONS ON THE CONTROL LEVEL: TESSA®

Cloud

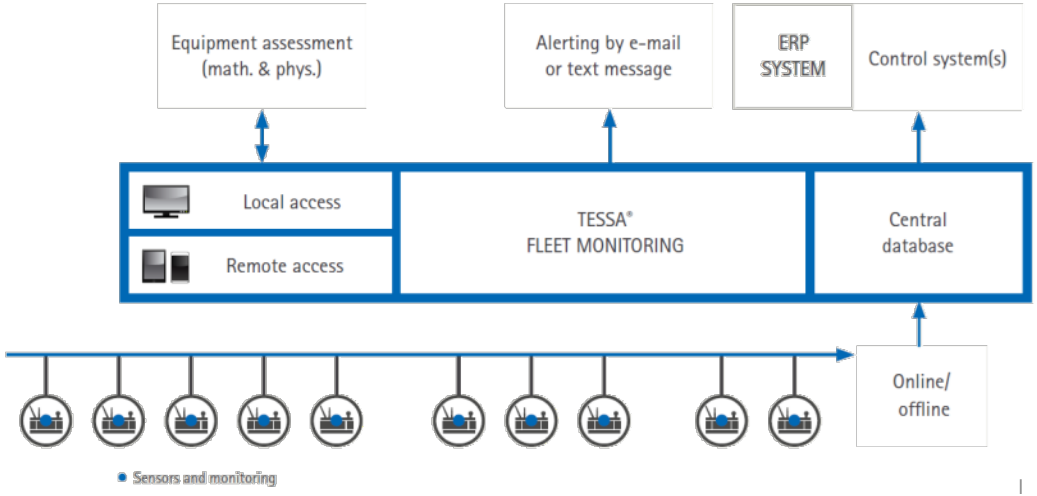
SCADA

TESSA®



Fleet monitoring TESSA®

- Automated real-time monitoring of all equipment, 24 / 7
- Central database with trend monitoring and equipment comparison
- Early, cost-effective elimination of consequences instead of cost-intensive repairs
- Savings in service activities, e.g. by extending maintenance intervals or reducing plant inspections



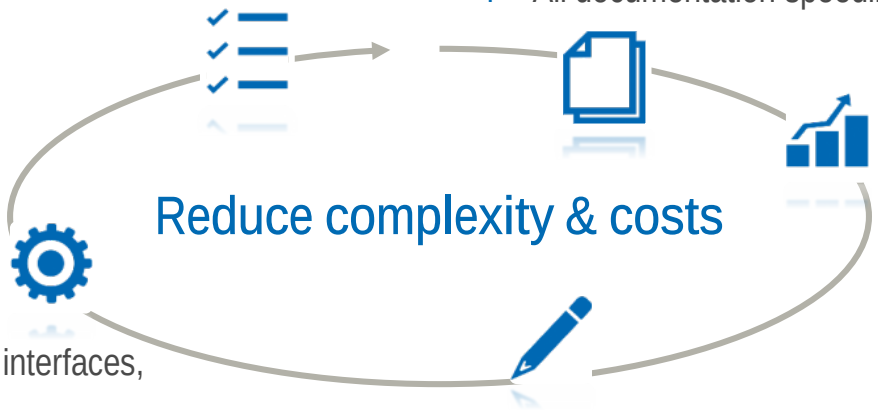
ADVANTAGES FOR TRANSFORMER MANUFACTURERS

Comissioning & service

- Documentation and commissioning wizard available right on the device
- Simple retrofitting
- Predictive maintenance
- Dedicated training and services available

Offer preparation

- Meet customer specifications through open & modular concept
- Fast & flexible price calculations and technical statements
- All documentation speedily at hand



Engineering & documentation

- One contact partner for secondary technical concept
- Open standards facilitate connection of sensors & devices
- Increase efficiency through function integration and innvovative top drive

Installation & testing

- Reduced user-orientated interfaces, gain in efficiency
- Benefit from automatic calibration testing and commissioning wizards

Logistics & procurement

- Raise planning security through our reliable logistics service

THE POWER BEHIND POWER.

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