

Transformers

VOL 6 ISSUE 4 OCTOBER 2019

MAGAZINE

INTERVIEWS:

Peter Schikarski
Cai Zixiang

COLUMNS:

Transformer lifecycle
Water in transformer
Transformer maintenance
Condition monitoring

TECHNICAL ARTICLES:

Mineral oils
Retrofitting bushings
Eco design



Resilient solutions for electrical power supply

Megacities ■ ABB's oil-free transformers ■ Ester transformer designs ■ Driving down losses
Transformers for renewables ■ On-line PD measurement and monitoring ■ Connection technology





Megacities

Resilient solutions for electrical power supply

1. Motivation

Cities offer higher living standards than rural areas, which motivates people in areas of lower standards to move to urban areas, causing the rise of population there. This is urbanization process, and it is one of the most pronounced modern trends. In some areas the effect is so strong that it turns cities into megacities. Megacity is a city with a population of over 10 million people, and in 2015 there

were 28 megacities globally with nearly 500 million people, which represents 6.5 % of the world's population! More than 50 % of these megacities are in Asia, such as the greater Shanghai area, Beijing and the Pearl River Delta in China. There is a strong tendency of urban growth and mega clusters situated in Asia, which alone is estimated to have at least 30 megacities by 2025. The biggest megacities in Africa are Lagos in Nigeria, Kairo in Egypt, Kinshasa in Congo, etc.

According to the UN, by 2050 about 68 % of the global population will live in urban areas. Higher living standards also generate the rise of demand for energy.

Based on the development phase, there are three archetypes of megacities, Figure 1:

- Emerging Cities
- Transitional Cities
- Mature Cities



In 2018, TRANSFORM Partners made a study on megacities and used it as a magnifying glass for clarifying challenges and needs of megacities and determining the key challenges of the future power supply



Figure 1. Three archetypes of megacities are differentiated, based on their development phase

In 2015 there were 28 megacities globally with nearly 500 million people, which represents 6.5 % of the world’s population; more than 50 % of these megacities are in Asia

Emerging Cities

Emerging Cities are characterized by young population and a high annual population growth rates - between 3 % and 6 % due to migration and birth rates. There is a high social polarity and big gaps in wealth, health, education, and political power between groups, where large population lives in informal settlements. It is typical for countries with urban populations of less than 50 %, such as Nigeria (Lagos) and India (Mumbai).

Transitional Cities

Transitional Cities are characterized by first signs of an ageing population and moderate annual population growth rates between 2 % and 3 %. It is typical for countries with urban populations of more than 50 %.

Mature Cities

Mature Cities are characterized by significantly ageing population and an an-

nual population growth rate of around 1 %. In some of these cities’ population has stagnated or is shrinking. The infrastructure was built one or two generations ago and it is typical for urbanized countries with urban populations of around 75 %.

In all three archetypes of megacities energy plays a very important role in the urban development.

2. Megacity Study - Challenges

Future challenges that will be faced in energy supply can be well understood by researching the ecosystem in megacities.

Hence, in 2018 TRANSFORM Partners decided to make a study on megacities and use it as a magnifying glass for clarifying challenges and needs of megacities and determining the key challenges of the future power supply, Figure 2 and Figure 3. The focus of the study was on the whole energy sector. Challenges that TRANSFORM Partners identified for megacities are also valid for regional and rural electric power supply.

TRANSFORM Partners engaged P3 to prepare the study. P3 is a renowned international engineering consultancy group with a global staff of more than 4000 consultants in key industrial sectors, including energy consulting.

During the study, 39 interviews with experts were conducted. They were from 17 cities worldwide, and half of them had local city agenda or grid operator background. TRANSFORM Partners also conducted interviews with OEMs and TRANSFORM Partners as well. Due to the impact chain - from megacity

Innovative products which address key challenges were developed and presented in the Innovation LAB during TRANSFORM Event in Hong Kong in September 2019

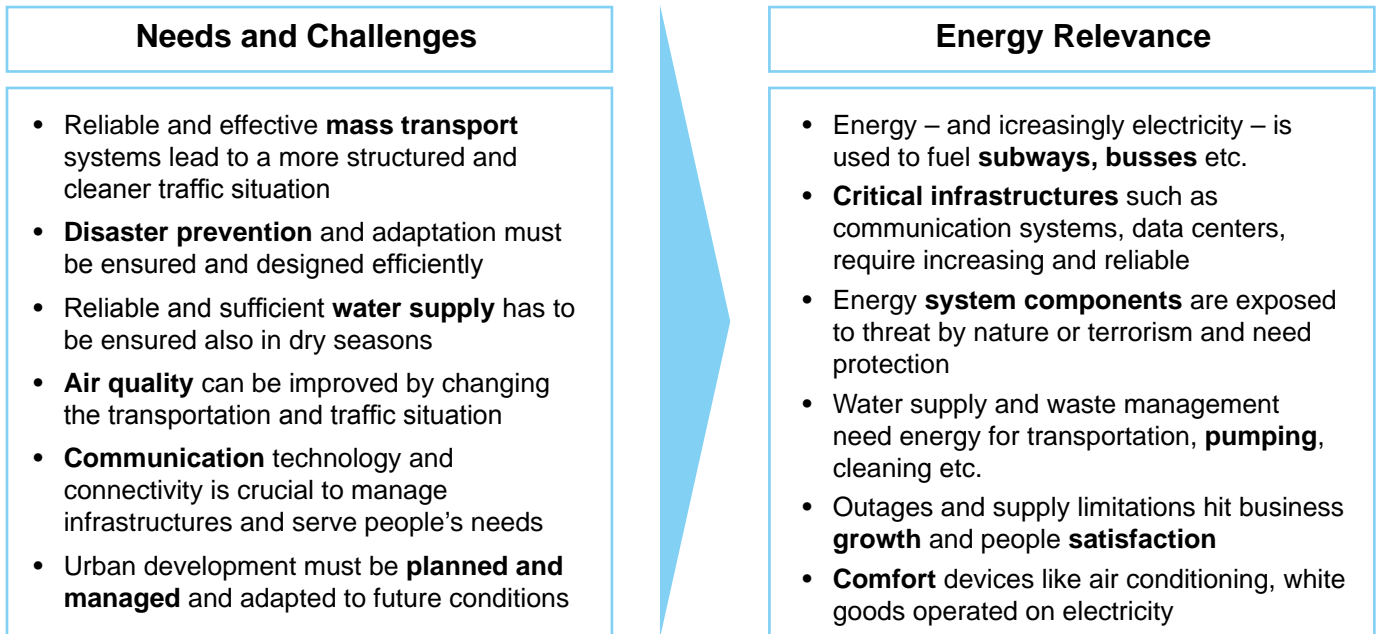


Figure 2. Needs, Challenges and Energy Relevance for an Emerging City

representatives' needs down to component requirements, interviewees with different background were chosen, Figure 4.

TRANSFORM Partners provided key insights into component technology requirements. Different requirements were identified in case of Emerging Cities and Mature Cities, Table I.

The interviews were conducted for the whole range of focus areas for grid operators to deal with, so that city targets can be achieved. Focus areas span across the

three main activity areas of grid operators: planning, design of system and assets, and safe and reliable operation, and they included: cost effective investment into energy infrastructure, extension of grid capacity, extension of transformer capacity, adjustment of grid structure, safe operation of assets, handling space limitations, etc..

The result of the study is a ranked list of technology requirements from areas such as: Operational performance, Resilience and Recovery, as well as Monitoring & Control, as follows:

1. Overload capability
2. Monitoring and Control
3. Lifetime Management
4. Efficiency
5. Grid Services
6. Modularity
7. Compactness
8. Environmental Impact

3. Solutions developed by TRANSFORM Partners

In order to address key challenges in electricity supply and fulfill the needs of stakeholders, TRANSFORM Partners

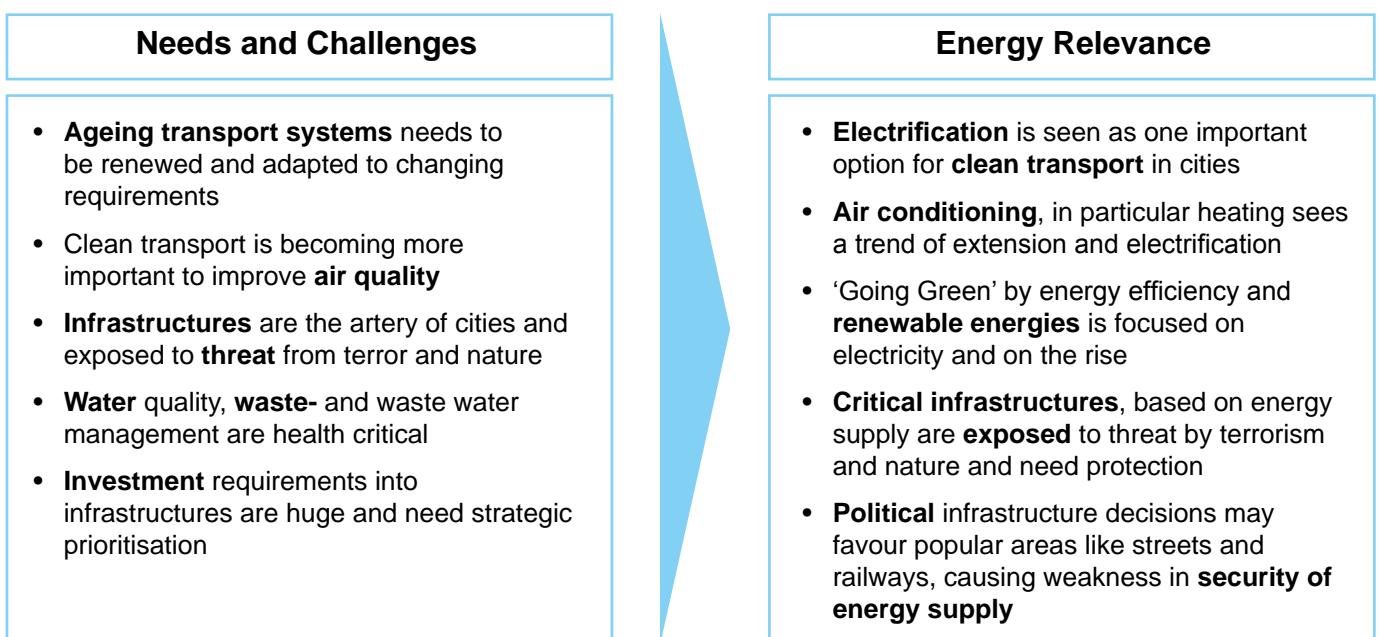


Figure 3. Needs, Challenges and Energy Relevance for a Mature City

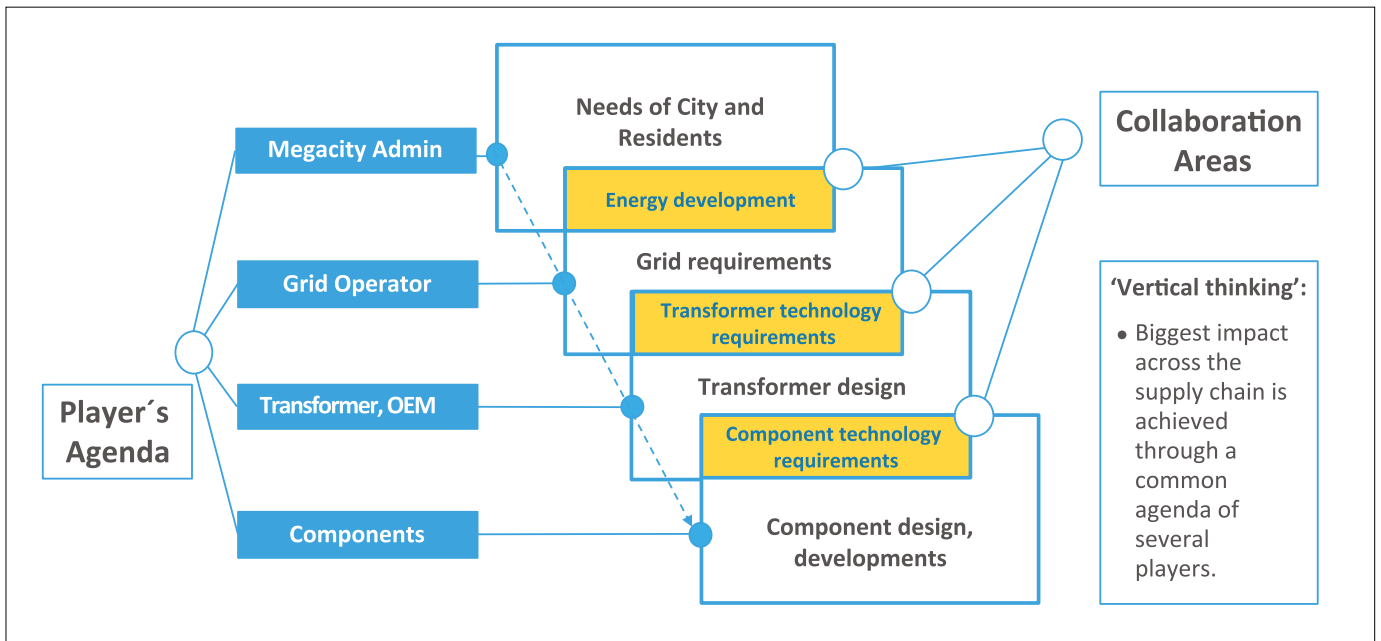


Figure 4. Impact Chain - from megacity representatives' needs down to component requirements

Table I. Different requirements between Emerging Cities and Mature Cities

Emerging Cities	Mature Cities
Demand	
<p>New connections through population growth Increase of electricity use per capita due to comfort (air conditioning, white goods etc.) Peak demand growing in shape and overall load</p>	<p>Only limited growth, if any Electrification of transport and heating next wave of power demand ('sector coupling') Hot spot areas – new office or shopping buildings – require local solutions</p>
Supply	
<p>Overall need to grow generation capacity Massive programs to build large scale Wind and PV outside the cities' area</p>	<p>Growth of small-scale renewables through incentive schemes Replacement of central coal, nuclear by gas, renewables (as far as possible)</p>
Consequence	
<p>Limited space for infrastructure build up in distribution system Capacity challenges in all voltage levels Transport and connection of large scale fluctuating renewable energy</p>	<p>Ageing assets increase risk of failure and outages Natural disasters playing increasing role for resilience Secure operation of critical infrastructure is top agenda</p>



Figure 5. Innovation LAB Transformer

developed innovative products which were presented in the Innovation LAB during TRANSFORM Event in Hong Kong in September 2019. The solutions cover following areas:

- Grid Operation and Control
- Transformer design “Transformer 2020 Evolution”
 - Transformer Control and Monitoring
 - Tap-Changer and Motor Drive
 - Transformer Fluid
 - Active Part
 - Bushing and Connection
- Diagnostic
- Asset and Fleet Management

Grid Evolution

One of strong drivers for grid changes is 'green' and emission-free traffic in megacities which, in terms of grid planning, bring into focus millions of electric vehicles and the associated charging station infrastructure.

PSI and MR have developed solutions for dynamic line rating and load optimization which are used for maximizing power line utilization and supporting dynamic overloading capability based on current and forecast data. Additional flexibility is ensured by using meteorological data and the option to pre-cool the transformer.



Figure 6. 'Green' and emission-free traffic in megacities is a strong driver for grid changes

New Transformer Design

The main attraction of the Innovation LAB is the Transformer 2020 Evolution, a modular, compact, mobile, resilient, high temperature transformer design shown as a mock-up based on a technology and design study, Figure 7. It combines modular plug and play solutions, compact and mobile design with high temperature components as well as an open intelligent and resilient operating system.



Figure 7. Transformer 2020 Evolution

Transformer 2020 Evolution is a modular, compact, mobile, resilient, high temperature transformer design with an open intelligent and resilient operating system

Bushings

A new bushing solution from HSP is based on resin impregnated synthetics (RIS), Figure 8. With homogeneous material properties and performance, it is less sensitive to humidity, environmental exposure and aging compared to organic materials, such as paper. The result is a higher reliability and availability.



Figure 8. RIS bushing

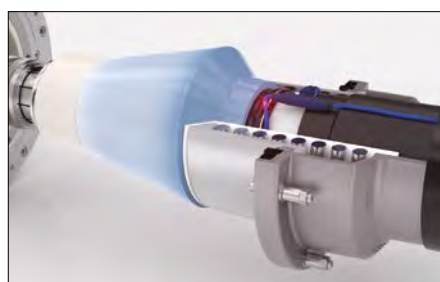


Figure 9. PFISTERER Smart Components

Connections

New PFISTERER's smart plug in connections allows the measurement of the most important operating data directly at the transformer interfaces, either via the socket or at the pluggable connector. Being smart at the interface, PFISTERER's Smart Components provide transformer operators the option to look into their equipment and learn more about the lifetime of their components by analyzing important operating data: voltage, current, temperature and power quality, Figure 9. This is a precondition for operating power grids more efficiently.

Windings

Insulating varnish films for winding conductors, although very thin, influence winding dimensions, filling factor, winding temperatures, i.e. overload capability and short circuit stability, Figure 10.

New ASTA epoxy varnish provides more mechanical and chemical stability, especially in case of short circuit events, as well as improving transformer's operating temperatures, enabling longer lifetime or higher overloading capability. The increase of the heat conductivity will lead to more mechanical stability of insulating varnish materials and it also leads to an improvement of the operating temperature of a transformer.

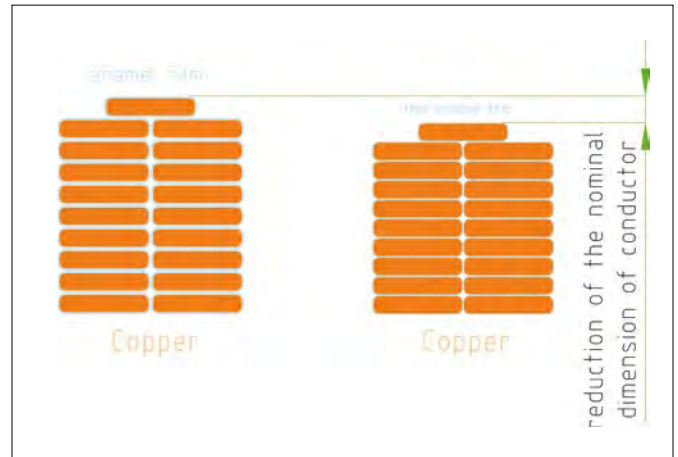


Figure 10. Compacting transformer winding using new ASTA epoxy varnish

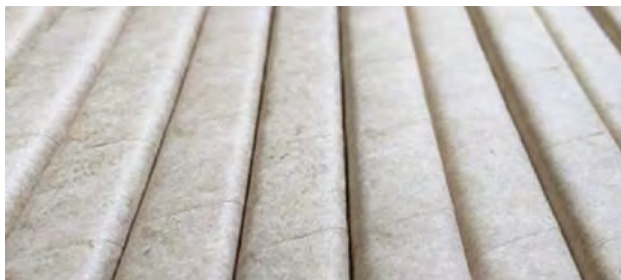


Figure 11. Rectangular conductor insulated with aramid-enhanced cellulose paper (DuPont)

Insulation system

DuPont's cellulose paper enhanced with Nomex® is a unique insulating material composed of high-quality electrical grade cellulose pulp and web-like binders made from the same high temperature polymer as other Nomex® brand papers, Figure 11. It allows increased overload capability for better flexibility, enabling meeting new regulation on increased efficiency. It is adopted for transformers operating with inverters and/or under high ambient temperatures (e.g. PV systems). It is also compatible with less flammable and biodegradable fluids enabling reduction of needed footprint.

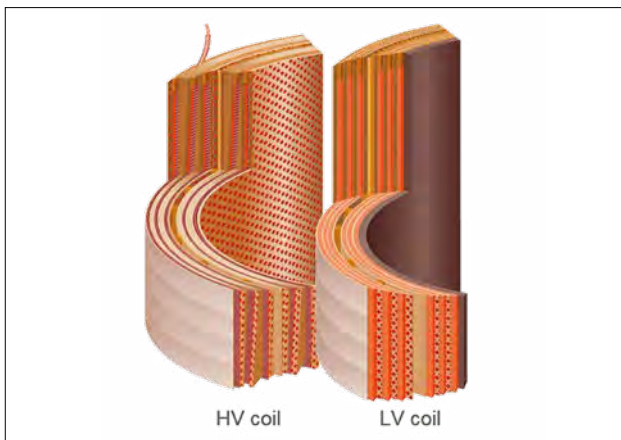


Figure 12. Insulation system for distribution transformers

Krempel's high temperature insulation systems for both high-voltage and low-voltage windings of liquid immersed transformers are based on Nomex® materials, Figure 12. These enhanced insulating components are giving new options for the transformer design in regards to reduced size and weight. In addition to that it is possible to increase overload capability of the transformer, extend lifetime and improve reliability of the insulation.

Lignostone® Transformerwood® (laminated densified wood) is a well-known insulation component from Röchling. With Lignostone® UHV a new grade is under development with unique electrical properties which makes it suitable for ultra-high voltage applications. It is also characterized by higher compressive strength and higher flexural strength.

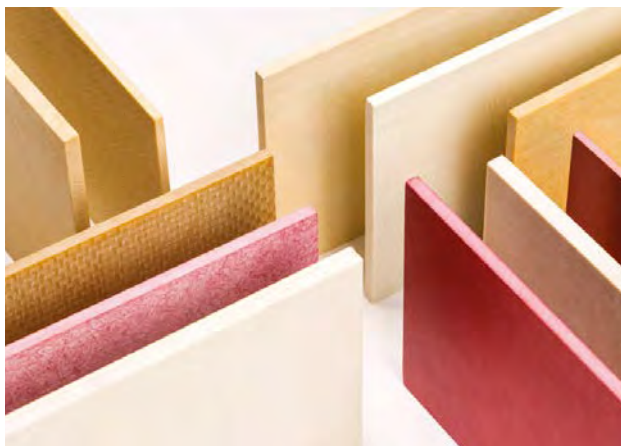


Figure 13. Röchling's DUROSTONE® offers new possibilities for improving transformer design in terms of efficiency, compactness, and resilience

TRAFBOARD® HD-PH is a laminated pressboard with outstandingly high and PD-free dielectric strength for higher performance. It is laminated using a special resin, which leads to better temperature behavior and allows overload operations. DUROSTONE® is a new product family for transformers, based on fiber reinforced plastics, Figure 13. With high dielectric strength, higher insulating class, and highest mechanical properties even at high temperatures, it offers new possibilities for improving transformer design in terms of efficiency, compactness, and resilience.

This material is suitable for segment rings, lead exits, press rings, pressure beams and exit frame.

Next generation high performance insulating liquid has outstanding heat-transfer capability and super-grade oxidation stability, based on renewable hydrocarbons

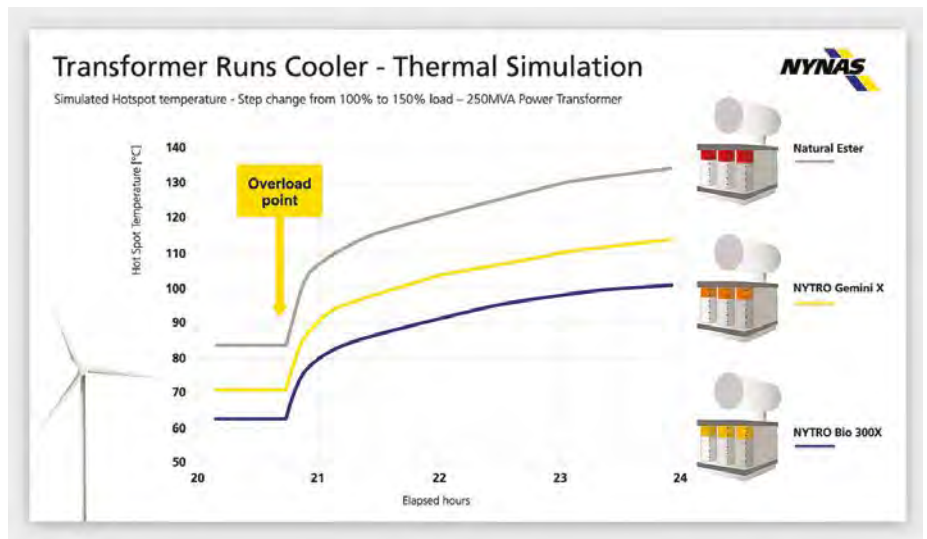


Figure 14. Outstanding cooling performance of new insulating liquid

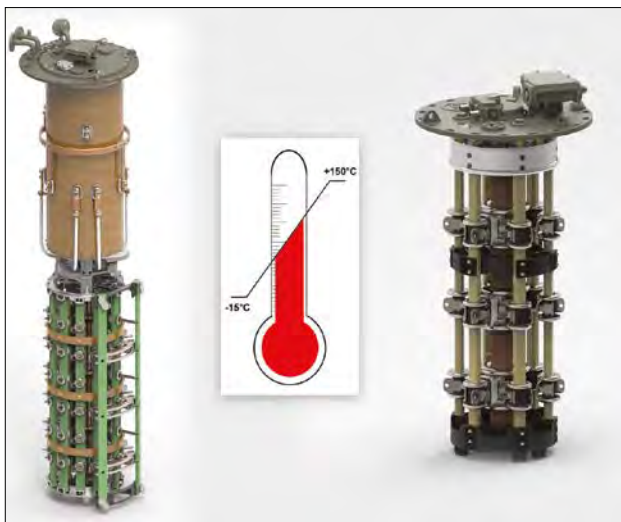


Figure 15. MR's high temperature OLTC and DETC



Figure 16. ETOS® control cabinet

Transformer Fluid

NYNAS NYTRO® BIO 300X is a next generation high performance insulating liquid with outstanding heat-transfer capability and super-grade oxidation stability, based on renewable hydrocarbons. Its ultra-low viscosity will allow fast processing times and improved thermal performance. It is readily biodegradable.

Tap-Changer

MR has developed a high temperature on-load tap-changer (OLTC) and de-energized tap-changer (DETC), which uses high temperature insulation materials, Figure 15. This enables it to use the higher thermal capability of esters during normal and disturbed operation, which results in an increasing grid flexibility, availability, stability and system safety.

Reduced size and increased power rating for highest possible overload capability enable designing transformers at lowest possible weight, making it ideal for mobile transformers.

ETOS®

MR's ETOS® (Embedded Transformer Operating System) is an open and modular automation system for reliable monitoring, control, regulation and digitalization of power transformers. The integrated solution for all automation functions on a transformer forms the heart of the digitalization solution. The combination of hardware components and software serves as the central interface between the process and control level. This is where all data from the individual transformer come together to be analyzed and evaluated. The open standard for digitalization can be used for transformers and sensors from all manufacturers regardless of age and power class. ETOS® is available in a range of designs and housing types – in the form of pluggable modules, a stand-alone version in a control cabinet, Figure 16, or an integration solution in a motor-drive unit.

ETOS® integrates tap-changer drive, voltage and cooling control as well as SCADA interface and monitoring into one control cabinet.

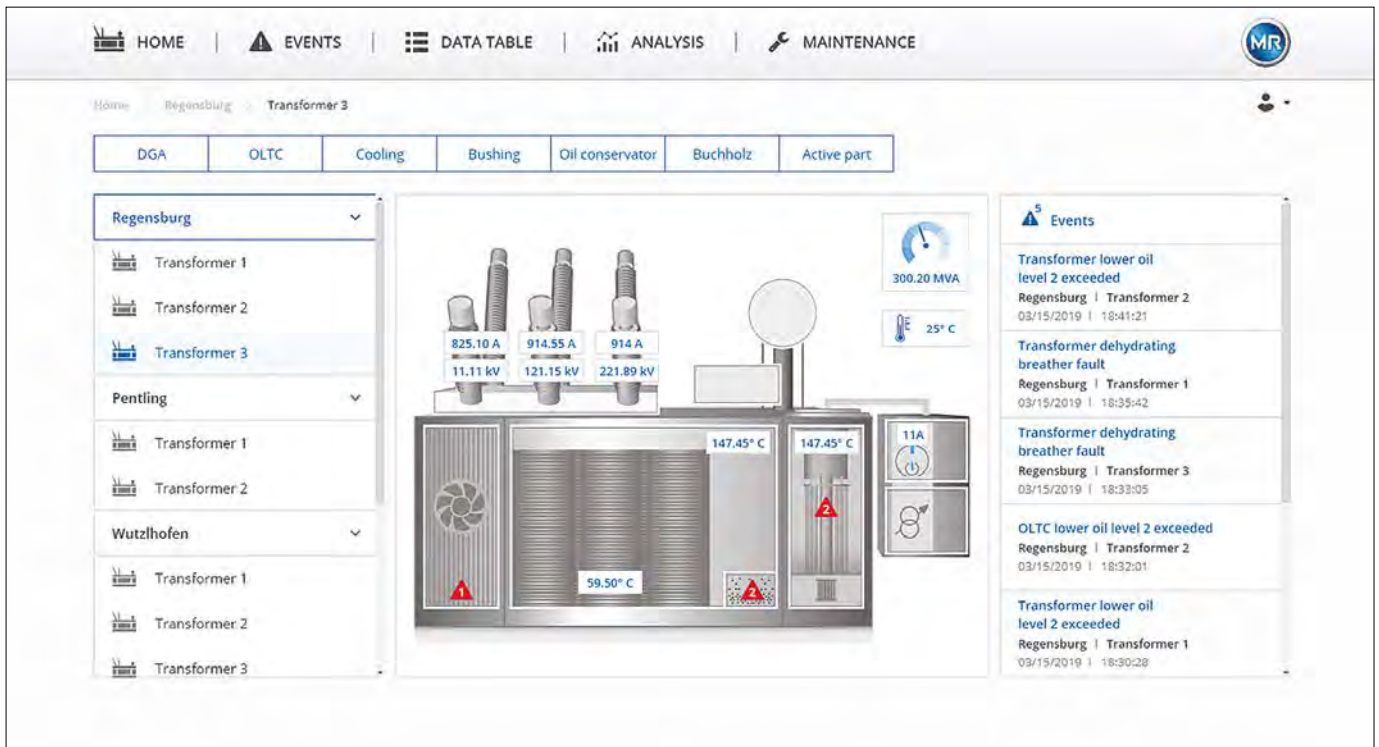


Figure 17. TESSA® FLEET MONITORING

TESSA® FLEET MONITORING

MR's TESSA® FLEET MONITORING is a new solution for collecting, visualizing and evaluation of data from all transformers in the grid, Figure 17. Its central database and algorithms enable automated and reliable trend monitoring, making it a tool for displaying the current condition data and asset lifecycle management of the whole transformer fleet in real time by using the existing communication structures as well as the field devices used on-site.

TESSA® FLEETSCAN 2D

The fleet management solution TESSA® FLEETSCAN 2D is a method for evaluation of criticality of components and systems in order to prioritize the required service and maintenance activities and, based on risk evaluation, supporting the asset manager in taking cost efficient decisions in the planning of maintenance activities and investments.

It helps to identify critical units at the right time and provide specific instructions about what action to take.

The two-dimensional approach considers the failure risk and the loss-of-life, Figure 18. The failure risk measures the likelihood of functions failing and supports the service manager for short-term maintenance decisions in order to ensure that the fleet continues operating reliably (OPEX). The loss-of-life index supports adopting the strategy for long term investment decisions in order to increase the fleet's service life (CAPEX).

Fleet management solutions have to provide means for evaluation of criticality of components and systems in order to prioritize the required service and maintenance activities

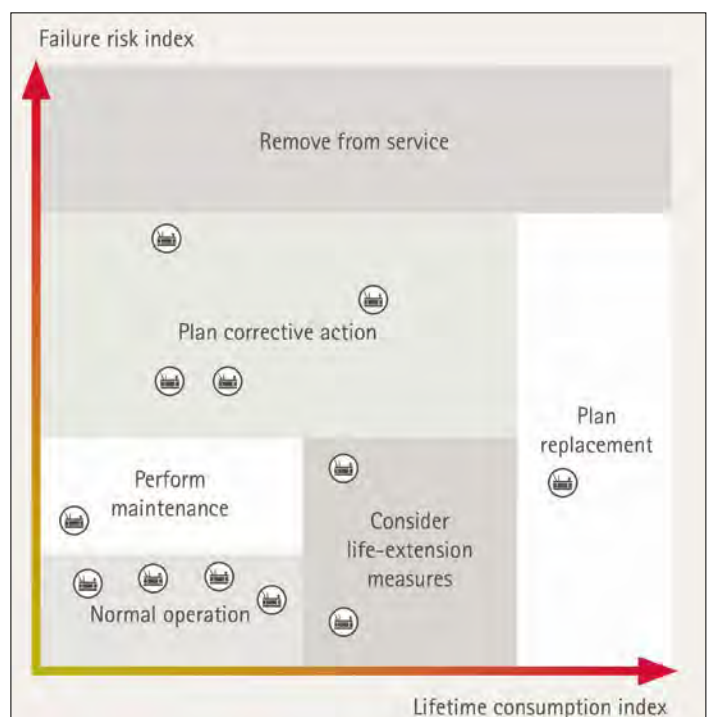


Figure 18. TESSA® FLEETSCAN 2D

On-Site Testing

In case of transformer condition deviations, additional diagnostic tools can be applied. Results of such measurements can be used to generate condition information and increase the quality of condition evaluation.

OMICRON TESTRANO 600 is the world's first portable, three-phase test system which supports all common electrical tests on power and distribution transformers, Figure 19. Compared to conventional single-phase test sets, TESTRANO enables performing various tests with the same setup, significantly reducing the connection effort and test time.



Figure 19. TESTRANO 600 – three-phase test system

OMICRON MONTESTO is a portable, on-line partial discharge measurement and temporary monitoring system for medium- and high-voltage electrical assets under load, Figure 20.



Figure 20. MONTESTO – portable on-line partial discharge measurement

Transportation on-site, installation and commissioning will cause one of the highest stress amplitude in the life of the grid components beside short-circuit failures in the grid. After such events, it is not certain that the equipment is still in the same condition as during factory test or generally before the event. Anticipating the criticality of transformers in megacities and the complexity of transportation and installation, electrical testing before energization is urgently required.

For the evaluation of the service conditions of grid equipment, the HiRES DEI (Dynamic Event Indicator) can be used to monitor highly dynamic changes of voltage and current in critical transformers. By using intelligent evaluation of this high resolution data, switching or lightning events and inrushes are evaluated, and even partial discharge activities can be indicated.

HIGHVOLT has developed on-site test systems which deliver sufficient power for effective on-site testing and enable execution of all the required tests possible for power and distribution transformers, cables and GIS, Figure 21.

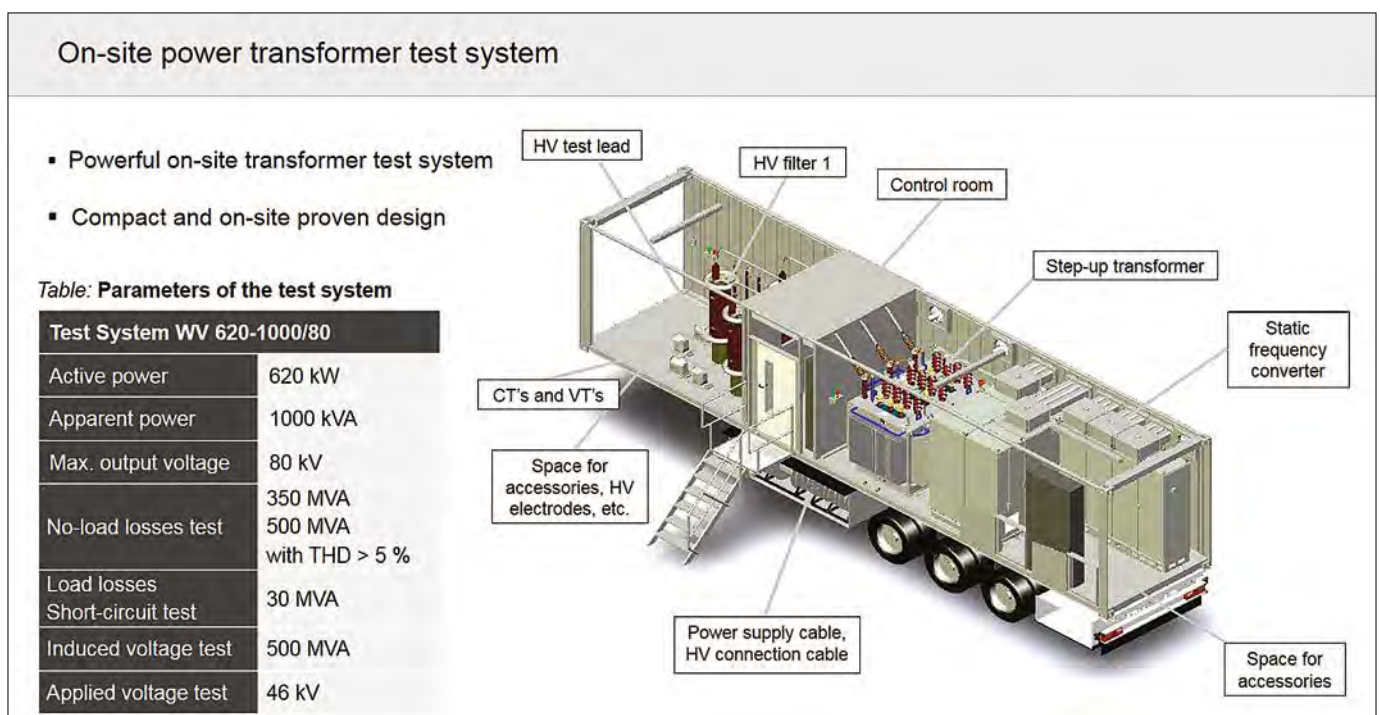


Figure 21. HIGHVOLT On-site power transformer test system