

OMICRON Magazine



VIBRO-ACOUSTIC MEASUREMENT
FOR ON-LOAD TAP CHANGERS



DEAR READERS,

In this edition, we will take you on a journey through the fascinating world of technology and innovation. We will present you with a selection of articles that provide insight into our latest developments and shed light on their practical relevance.

We begin with an analysis of the long-term collective challenges that we face. The article on page 26 delves into current developments in the energy sector and associated challenges. You will gain valuable insights into this complex topic and learn how innovative solutions can help avoid future supply shortages.

Next, we have an article written in collaboration with our client, BASF. It explores how one of the world's largest chemical companies uses data to optimize processes while increasing sustainability and efficiency. A fascinating behind-the-scenes look demonstrates how data analysis and sustainability can go hand in hand.

Another highlight is the report on developing a new measurement method for Capacitor Voltage Transformers. On page 32, you will discover how precision in electrical engineering not only contributes to efficiency but also enhances safety.

Furthermore, explore the importance of certifications by using the example of the BSI certificate we recently received for our StationGuard intrusion detection system. Learn how a small seal holds special significance for quality assurance and why it means more to us than just a certificate.

In summary, each of these stories is linked by a central theme: innovation and its influence on our future. Whether it's challenges in service and repair requests, the transformative power of data usage, precision in measurement technology, or the significance of certifications – all these articles illuminate how technological advancements and innovative strategies can help us collectively overcome the challenges of tomorrow.

I hope this edition of the OMICRON Magazine will enrich and inspire you. Your feedback always helps us improve new editions – please share your thoughts with me. I look forward to hearing from you.

Yours sincerely,

Lia Thum

Editor in Chief, OMICRON Magazine

Publisher

Responsible for content

Editorial team and implementation

Picture credits

E-mail to the editorial team

OMICRON electronics GmbH, Oberes Ried 1, 6833 Klaus (AT)

OMICRON electronics GmbH

up! consulting, Industriering 10, 9491 Ruggell (FL)

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magazine@omicronenergy.com

*«Imagination is more
important than knowledge,
for knowledge is limited,
**whereas imagination
embraces the entire world,
stimulates progress, and
gives life to evolution.»***

Albert Einstein

TABLE OF CONTENTS



6 Good vibrations

Listen to your on-load tap changer, it may be trying to tell you something.



9 ASH1 – highest flexibility for optical scanning heads

Our new adapter that connects optical scanning heads through binary inputs.



10 Ready for the challenges of a zero-emission future

In collaboration with OMICRON, BASF shows how to successfully introduce a new data and testing strategy.



14 A test set ballet

Service Hubs open up around the world.



18 See and understand

Get a better overview with CPOL3 for wiring tests.



20 Our cybersecurity system shines with distinction

OMICRON receives security certificate from the BSI.



22 How to verify suspected insulation faults in power transformers





26 No shortage of shortages

Impact of the component crisis on the energy sector.



29 What's new in Test Universe 4.40?

Greater scope for your tests.



30 Circuit breaker testing around the world

How are circuit breakers being tested on different continents?



32 A blackout is followed by a black start



36 On site: OMICRON in Georgia

Ivane Sachaleli from LTD Tranfiber-Service gives us his insight into the power sector.



38 Determining the C-divider capacitances of a Capacitor Voltage Transformer

Developing a new measurement method.



42 A worthwhile commitment

Why engaging within electrical engineering societies makes sense.



KNOWLEDGE



SUPPORT



INNOVATION



QUALITY



GOOD VIBRATIONS

Listen to your on-load tap changer, it may be trying to tell you something.

The on-load tap changer (OLTC) is an essential component of a power transformer that helps maintain a stable voltage level within the electrical grid. It adjusts the transformer turns ratio, which regulates the system voltage. Various diagnostic tools are available to assess the static and dynamic characteristics of the tap-changer. While a DC winding resistance measurement can reveal wear and tear of the main contacts, the dynamic resistance measurement is sensitive to timing changes and current interruptions during the switching operation.

The vibro-acoustic measurement (VAM) is a new tool in the diagnostic toolbox that records the vibrations produced during switching operations. This means that all the OLTCs' components that create a certain vibration level can be analyzed and evaluated. It's even possible to conduct an in-depth condition assessment by combining it with our well-established dynamic resistance measurement (DRM).

The best results are achievable when the VAM and DRM readings are compared with reference data, either from the same unit or a comparable sister unit.

VAM signals are obtained using magnetically mounted sensors installed on the transformer tank. This connection technique allows the operator to record vibration signals while the transformer remains in service. Consequently, potential changes in the OLTCs' mechanical integrity can be detected early between maintenance cycles without an outage. By doing this, the VAM can help prioritize individual units for the maintenance schedule.

Paweł Molenda is a member of the board and deputy technical director of OBRE Poland. He performs on-site transformer diagnostics and gives technical advice in the transformer and HV equipment fields. He shared the insight he gained when he used the TESTRANO 600 and the VAM1 during his maintenance work on various on-load tap changers. Along with Tomasz Bednarczyk (Application engineer at OMICRON), Paweł and his team conducted several vibro-acoustic measurements to gain more profound knowledge about the OLTCs' condition.

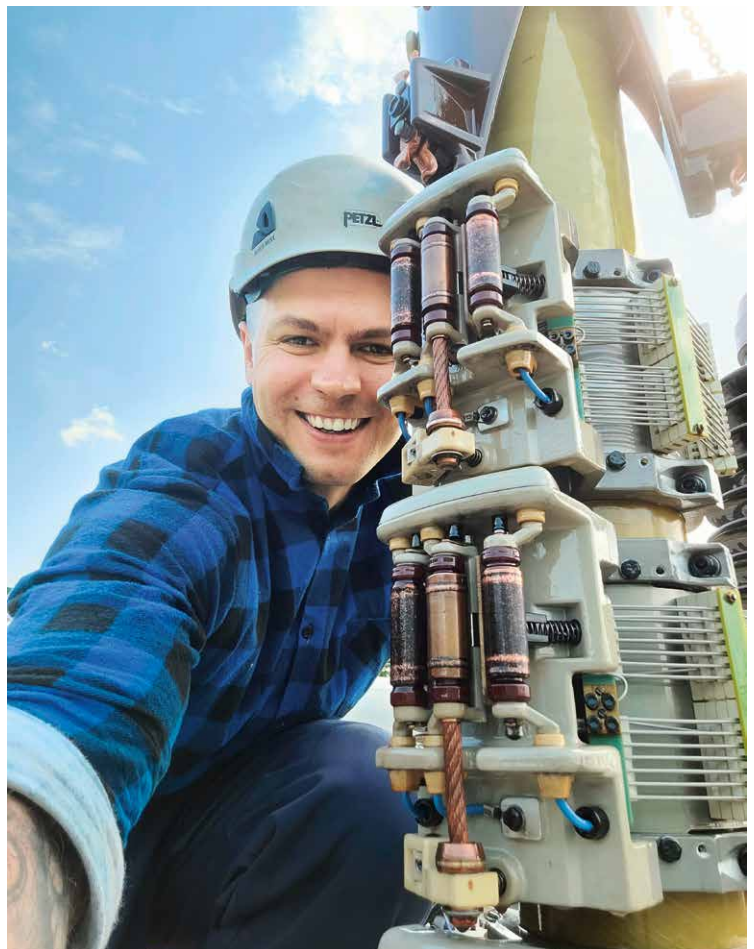
Paweł, what is your typical testing scope for power transformers?

Paweł Molenda: The scope and purpose of the test must be tailored to the client. We conduct on-site measurements in the periodic, post-installation, and post-failure measurement fields as part of our measurement activities. This includes testing the insulation state using polarization methods and measuring partial discharge using electric and acoustic methods. To summarize, we offer our clients all types of diagnostic measurements, from basic electrical tests to in-depth condition assessments. We perform measurements according to IEC and IEEE standards and follow customer instructions according to their requirements. ▶

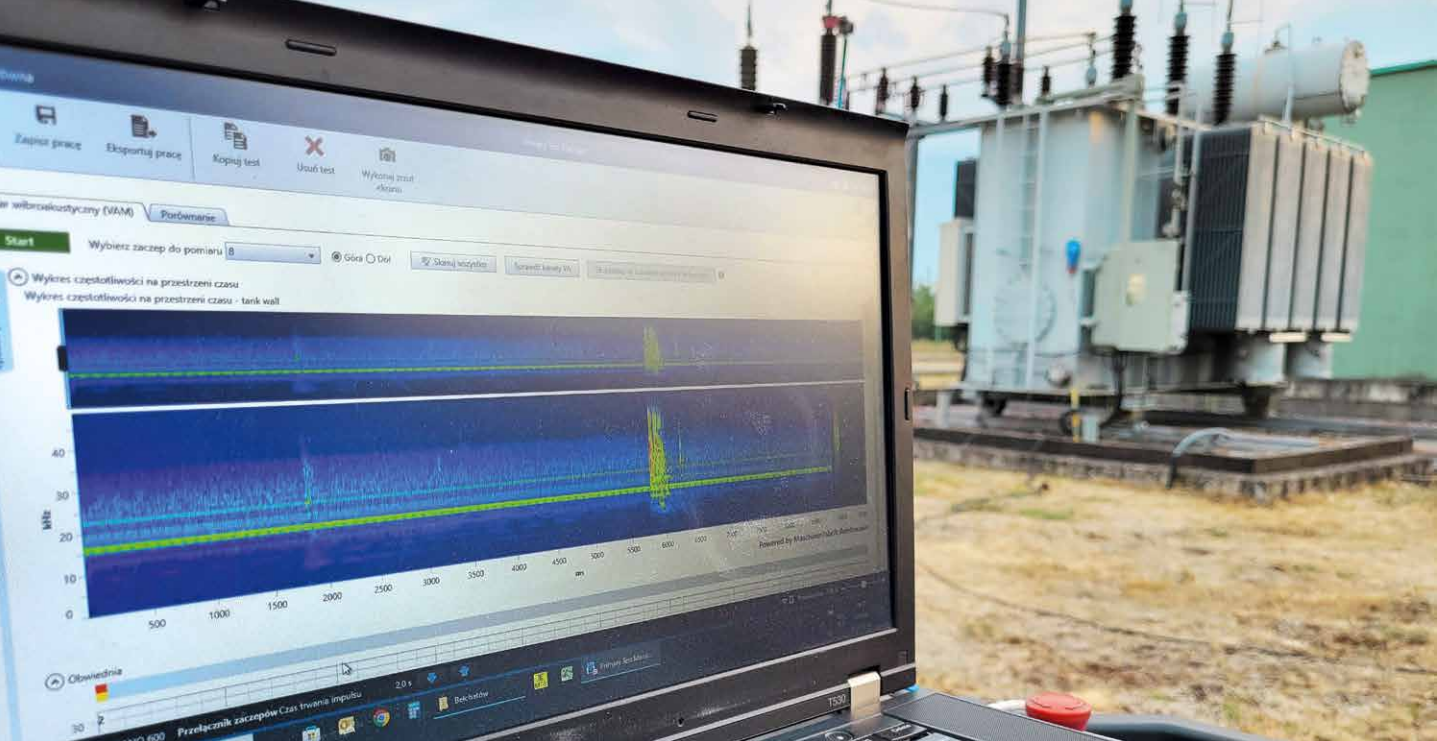
*«Vibro-acoustic measurements are a good method for initial tap-changer diagnostics **that provide a quick and cost-effective initial assessment.**»*



Paweł Molenda,
Deputy technical director,
OBRE



Tomasz Bednarczyk, Application Engineer, OMICRON



What are the typical maintenance activities you conduct on OLTCs to ensure they function properly and their lifespan is prolonged?

OLTC assessments are based on a DRM measurement and internal inspection of the diverter switch inserts. We adopt the appropriate diagnostic procedures depending on the number of OLTC switchings. First, we perform oscillographic measurements (DRM). Next, we set up an internal inspection for the tap-changer head, check the main and auxiliary contacts' quality and the springs. Finally, we perform oscillographic measurements again to ensure the asset functions correctly. Thanks to these measurements, we can adjust the maintenance scope to increase the lifespan of the OLTC.

How much experience do you have with dynamic resistance (DRM) and vibro-acoustic measurements (VAM) on OLTCs?

We have performed oscillographic measurements for 20 years. In addition to that, we have been conducting OLTC vibro-acoustic measurements for a year now. We often used our MT3 device

for this type of measurement. For some years now, we have only been using OMICRON measuring devices, and the recent addition of OLTC vibro-acoustics and our cooperation with OMICRON has enhanced our experience.

What are the benefits and limitations of these methods?

Measurements are the first step in assessing the technical condition of the on-load tap changer. The benefit of this is that it provides a quick and cost-effective initial assessment of the asset's condition. However, correctly evaluating the on-load tap changer is only possible after the condition of the contacts and the OLTCs' mechanism have undergone internal inspection and visual checks.

What stages of the maintenance cycle do you apply these methods to, and how do you interpret and analyze the results?

Typically, they are performed before and after maintenance work, but sometimes, they can be performed more frequently between inspection intervals and electrical measurements. We then compare our results with our

customers' standards, norms, similar switches, and experience.

Does measuring OLTCs help facilitate the maintenance and maintenance schedule of the unit?

Absolutely. OLTC measurements help predict the operation time and repairs for the tap changer, while the online vibro-acoustic measurement is a quick method for initial tap-changer diagnostics. These methods provide a quick and cost-effective initial assessment of the OLTCs' condition, which can help prevent costly downtime and repairs in the future. In some cases, Diverter Switch Insert (DSI) defects can be diagnosed earlier between transformer inspections, and vibro-acoustics can help assess the OLTCs' technical condition much earlier without taking the transformer out of service and conducting a costly inspection. If the method and analysis of the results are refined, online vibro-acoustic measurements offer excellent opportunities for scheduling the OLTC for maintenance in the future.

Thanks for the interview. ■

ASH1 – HIGHEST FLEXIBILITY FOR OPTICAL SCANNING HEADS

Our new adapter that connects optical scanning heads through binary inputs.



Optical scanning heads are usually used for counting optical energy pulses during energy meter testing with a test set like our CMC or something similar. Scanning heads can also read status information from protection

relays indicated by LEDs and convert them to binary signals for testing. The following examples illustrate how you can benefit from the ASH1 adapter and its new possibilities.

ENHANCE YOUR DEVICE

ASH1 allows you to connect an optical scanning head for relay testing to devices previously unable to do so by using binary inputs. For example, you can now use a COMPANO 100 to convert the LED indications from protection relays into binary signals and use them in test sequences, e. g., for assessments or trigger conditions. Using the COMPANO 100 as a battery-powered and portable device combined with the OSH 256R, a universally mountable optical scanning head for relay testing, is the ideal choice for portable and flexible testing.

OSH 256R mounted on a protection relay



ASH1 adapter



BECOME MORE EFFICIENT

ASH1 allows you to connect more than one scanning head for meter testing to the binary inputs of your test set, such as the CMC 430. This makes testing more efficient because you can count active and reactive energy pulses without interrupting the test to change the scanning head position. To equip you with the proper scanning head for your meter test applications, we offer you three different sets for counting the optical LED pulses of digital meters or the rotor marks of electromechanical meters. ■

 omicron.energy/ahs1

READY FOR THE CHALLENGES OF A ZERO-EMISSION FUTURE

In collaboration with OMICRON, BASF shows how to successfully introduce a new data and testing strategy.





The BASF Ludwigshafen site is the largest integrated chemical complex in the world. It spans some 8 km² | 3 mi² and has around 39,000 employees. As well as being connected to the Amprion grid, the site has three power plants with a total capacity of approx. one gigawatt. The entire site currently requires around 6 terawatt hours of energy per year and an average electrical capacity of 750 megawatts at a power density of approx. 100 MW/km² | 40 MW/mi². The power supply for the complex comprises:

- › >20 substations in the transmission grid
- › >160 substations in the distribution grid
- › >4,900 feeders
- › >6,400 protection relays

Various device generations, manufacturers, and types, as well as the use of different protection concepts add to what is already a complex situation. The effort involved in maintaining the entire infrastructure is equally complex and challenging. However, the sheer scale of it also offers enormous potential for optimization in terms of the testing strategy and processes.

In an effort to take the existing tasks in the area of protection technology to a new level using the resources available, Svenja Rogalski, Christian Schumacher, and his team have analyzed the situation in detail and embarked on an ambitious project. The project team

has worked with us on this basis to develop a new data and testing strategy. The goals were clear:

- › On the one hand, the team wanted to establish a basis for higher data and test quality in order to improve the efficiency of the resources used.
- › On the other hand, they also focused on enabling troubleshooting and network expansion for the upcoming energy transformation with the existing team.

The strategy revolves around our data management solution ADMO, which enables the straightforward management of assets, configurations, test templates, and test results while also ensuring their quality.

No transformation is without its challenges

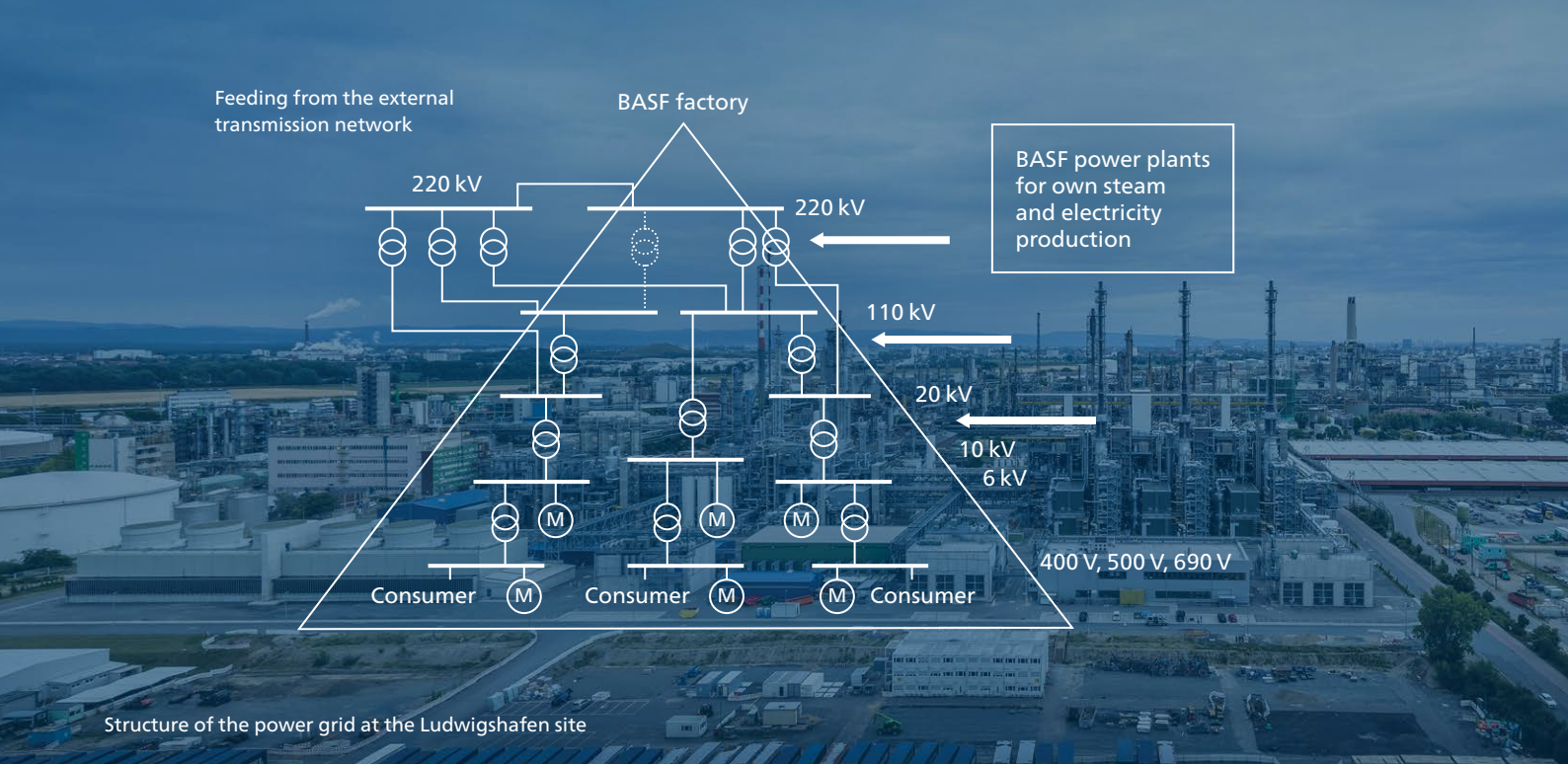
The situation described above is just the starting point, however. BASF has set itself the company-wide goal of reducing its greenhouse gas emissions to net zero over the coming decades. To achieve this goal, the electrical capacity needs to be doubled to an average of 1.5 gigawatts. This poses challenges in terms of generation, transmission, and the distribution of the energy.

This high demand is due to the technological changes required to reduce CO₂ emissions. In the future, BASF will rely on industrial heat pumps and compressors, as well as electrically heated steam cracker furnaces. The carbon-neutral generation of hydrogen involves ▶



*«The team really got locked in and was clearly enjoying protection testing again. **The opportunity to help shape the new processes really motivated everyone.**»*

Christian Schumacher,
BASF



two processes: water electrolysis and methane pyrolysis. The energy infrastructure needs to be expanded to accommodate this, and that requires new grids and substations to be established and the existing ones on the BASF site to be expanded. This involves the installation of a lot of additional assets, which not only need to be commissioned but also then have to be maintained every five years.

Sequence of previous testing strategy

During the preparation of the project, the team led by Christian Schumacher first examined the existing testing strategy. Previously, protection protocols were created using MS Excel templates that combined the setting sheet and the test report in one form. These MS Excel templates were populated semi-automatically using the asset database. All basic data, such as the protection device type, transformer ratio, etc., for the test case at hand, were checked and then typically sent to the testers, usually by email. The final protection protocol was then taken to the substation in printed form by the tester. The responsible team member performed the test, recorded the relevant values in the protection report, and then signed this report by hand. Finally, the document was scanned and stored in the asset database.

The previous testing strategy had the following disadvantages:

- › The test teams responsible for the transmission and distribution grids had different test approaches.
- › The test points did not have tolerance specifications.
- › There were very few test points.

- › General uncertainties regarding the testing procedure and results among the protection testers
- › Incomplete quality assurance of the many manual work processes.
- › There was no reliable data source due to the lack of clear, standardized documentation.

Setting course for the future

Stefan Schöner and Michael Albert were on hand to advise the project team while developing the new testing strategy based on ADMO. The focus was on establishing standardized work processes across all test teams and, more generally, on improving data quality – two areas in which our data management system ADMO, in combination with Test Universe and CMC test devices, are ideally placed to support end users.

Standardized protection tests have been and continue to be defined for the entire site as part of the ongoing project. These tests are easy to understand for all teams because detailed test templates and instructions are provided. They can also be compared one-to-one with tests that have already been carried out. Even after just a short amount of time, a lot of the insecurities that prevailed among the protection testers have eased. ADMO offers a central location where all necessary relay and test documents can be found in one place. There is also no longer any need to enter test results manually. They are automatically synchronized with the central ADMO database and securely stored as soon as the testers connect to the company network. Eliminating the



need for manual intervention improves the resulting data basis and makes the data analyses performed based on this data more meaningful. Going forward, the ability to compare data collected in a standardized way will also enable more informed statements to be made about the history and condition of the assets.

The collaboration with external service providers has brought other benefits for BASF:

- › For both commissioning and maintenance tests, project data can be transmitted securely, in full, and in a traceable manner.
- › The specifications and the scope of the required tests can be clearly defined using the templates and reports.
- › Any changes are documented thoroughly and reliably.

The development of a new testing strategy, like at BASF, always involves a certain amount of effort to start with. However, it very quickly generates significant benefits, particularly in terms of more efficient processes for the preparation, execution, and documentation of tests.

Ready for phase 3

The implementation of the project has been divided into three phases. BASF has already successfully implemented phases 1 and 2 with us. The focus of these phases was on ascertaining the current situation, including the level of knowledge among staff, sharing knowledge, and developing the initial test templates. With our training on the basics of protection technology, the definition of a test

specification, and our recommendations on testing strategies, we brought all protection testers up to the same level of knowledge. Following on from this, the next step was to develop test templates within several working groups. For the distribution grid, test templates were created for inverse-time overcurrent protection/definite-time overcurrent protection, line differential protection, and motor protection. For the transmission grid, templates are now available for distance protection, transformer differential protection, and busbar protection. In the current phase of the project – phase 3 – BASF is now pressing ahead independently with the implementation of the new testing strategy and including additional protection types and devices. Our experts are on hand and available to provide support as required in this phase too.

Making protection testing fun again

The excellent results demonstrated how motivated the working groups were to get locked in and make some changes. We were particularly pleased to see that by sharing our experience and knowledge, we were able to reduce insecurity in day-to-day work. According to Christian Schumacher, it is also clear that employees are enjoying protection testing again. Last but not least, thanks to the project and the use of ADMO, protection, testing, and parameterization data is now used with much greater awareness at BASF. Although the achievement of net zero may still be some way off, BASF is now well equipped to tackle the challenges ahead with its new data and testing strategy. ■

A TEST SET BALLET

Service Hubs open up around the world.

As the enormous entrance door of the OMICRON Service Hub in Klaus opens and slides upwards, it's almost like watching a heavy stage curtain rising to reveal the set. The countless yellow boxes roll out onto the dance floor – disguised as a loading ramp – and take their positions. The choreographer of this test set ballet is Roman Novak, who, together with his team, is now setting off on a world tour with this show.

When the very first OMICRON Service Hub opened at our head office in Klaus at the beginning of 2021, there was no orchestra to be heard, nor was anyone tapping out a rhythm with the familiar „and one-and-two-and-three ...“. Yet the precision behind the planning and timing of all the processes undoubtedly resembled sophisticated choreography. Everything must be perfectly coordinated to ensure the entire process runs smoothly and efficiently. The aim of this project was to create a one-stop shop for all our service and repair requests. In addition, the design of the hub and the lessons learned from this pilot project serve as a blueprint for our other sites. Now, almost three years later, the test phase is complete, and the Service Hub concept is being rolled out around the world.

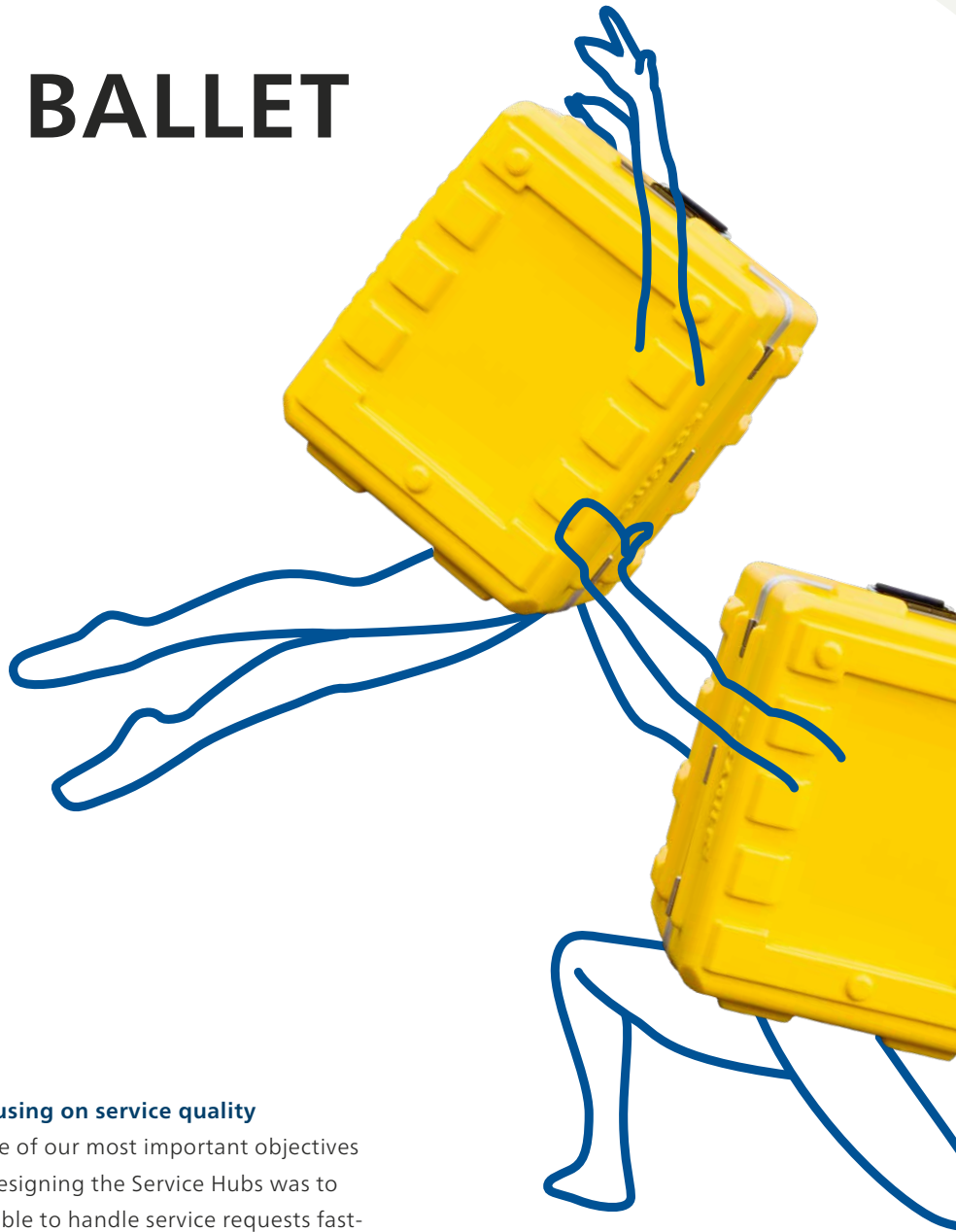
Focusing on service quality

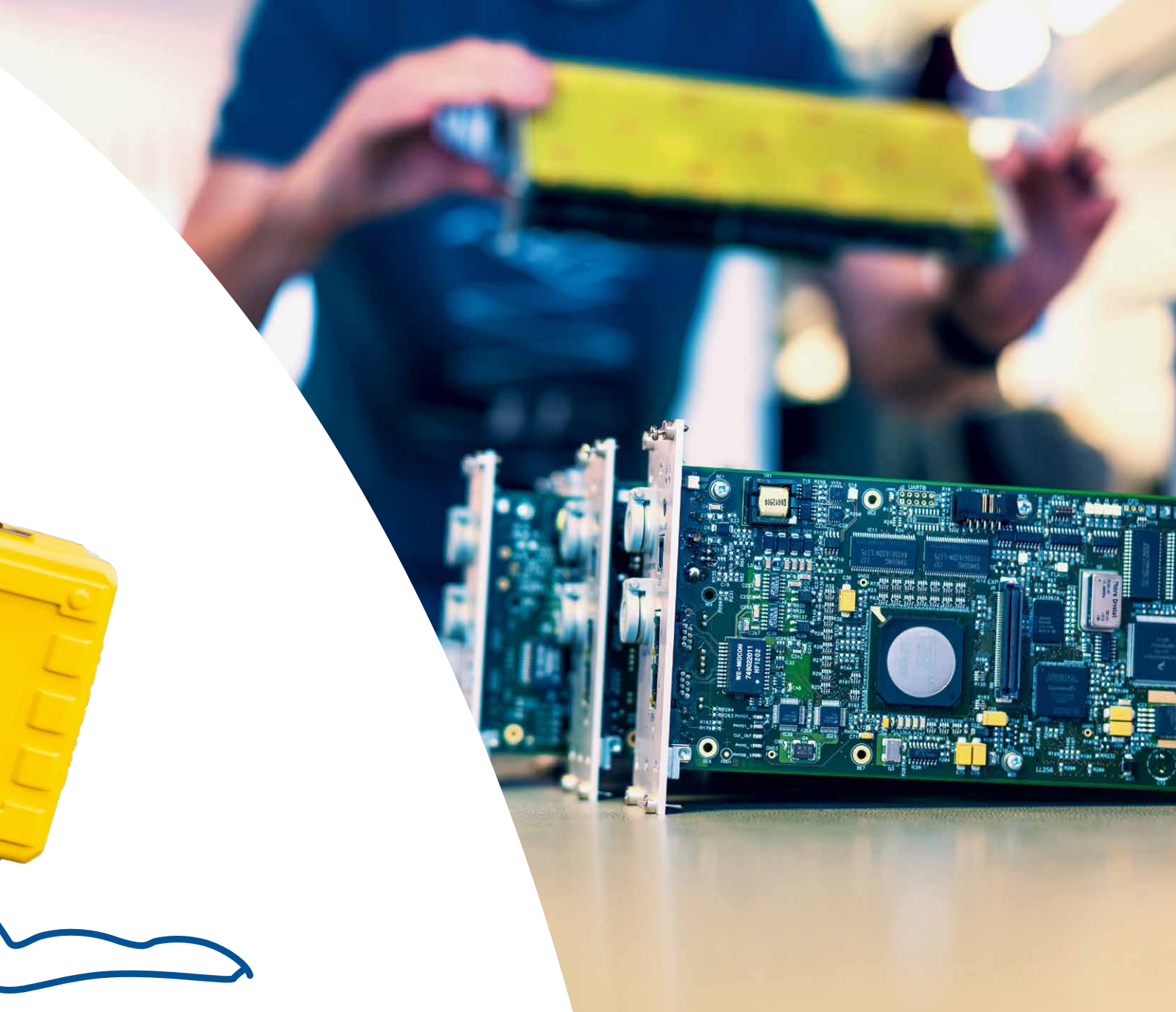
„One of our most important objectives in designing the Service Hubs was to be able to handle service requests faster and more efficiently. The hubs had to operate completely independently of our day-to-day business activities to achieve this. Even major company-wide projects should have zero impact on the hubs so that our customers can always expect a consistently high level of service quality“, explained Roman, manager of the Service Hub in Klaus. „We operate autonomously. Besides all the technical aspects of our service activities, the team handles the entire process from beginning to end. From order clarification to logistics – regardless of whether the request is for a calibration, an adjustment, a repair, or an individual service call-out. We

also handle callbacks ourselves. For example, a test set may arrive in the workshop without any error description. We then contact the customer directly to ensure that the test set is functioning again as soon as possible. From the time they arrive in the hub to their dispatch, test sets remain with us for an average of five days.

Global standard, local service

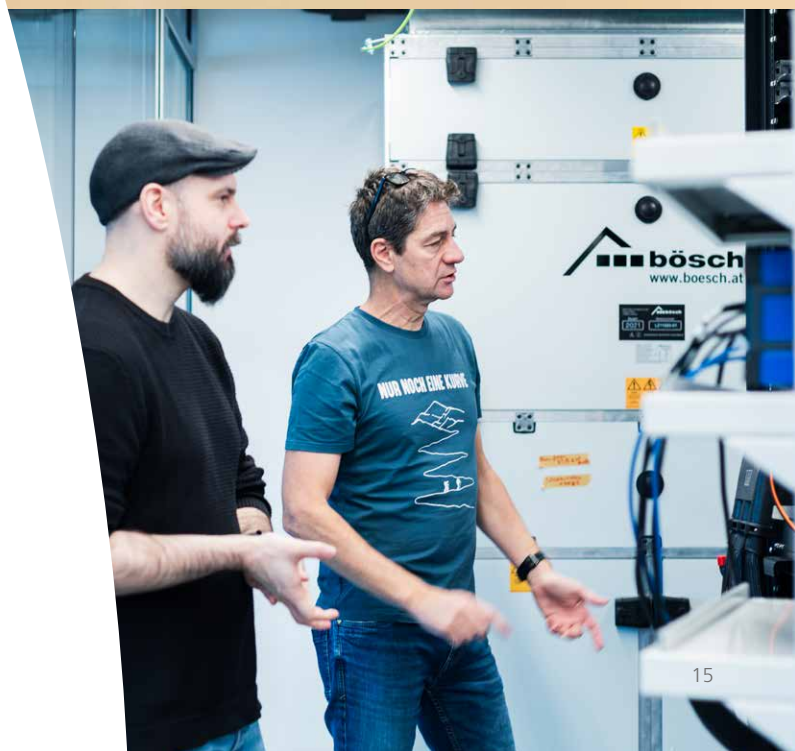
Targeted standardization is what allows us to provide such prompt service. Like a carefully planned stage performance, every service activity ▶





«One of our most important objectives in designing the Service Hubs was **to be able to handle service requests faster and more efficiently.**»

Roman Novak,
Process Manager, OMICRON



«In summary, we can say **that the pilot project in Klaus has been a resounding success**, and the concept has proven itself with the opening of the Service Hub in Houston.»

Roman Novak, Process Manager, OMICRON

follows a meticulously structured sequence. In addition to the processes, workplaces have been standardized as well. In every Service Hub across the globe, employees use the same infrastructure and equipment – the same tools, software, and, naturally, spare parts. Whether a team member is working in the Service Hub in Klaus, the Service Hub in Houston, which opened last year, or in one of our future hubs in Asia or Australia – they should always feel they're working in a familiar environment.

Apart from standardization, future sites also play a significant role in optimizing service times. For example, test sets no longer have to be returned to Klaus to be adjusted; they can be calibrated on-site. That's why every Service Hub has climate-controlled rooms with multi-test towers.

Networking the hubs

Even though the Service Hubs operate autonomously, they remain closely linked. „The hubs are networked together so that a regular exchange of knowledge and ideas can occur. The benefit of this is that when a problem has been resolved at one site, all the others benefit from the experience without having to find solutions of their own.“ this is how Roman gives us a glimpse into the collaborative process between individual Service Hubs. „In summary, we can say that the pilot project in Klaus has been a resounding success, and the concept has proven itself with the opening of the Service Hub in Houston. We're looking forward to opening additional sites and extending the reach of our high-level service quality.“ ■



Service Hub backstage pass

We've prepared a short Service Hub presentation video to give you an idea of what goes on behind the scenes at the Service Hub in Klaus. Scan the QR code to see what's going on behind the curtain.



 omicron.energy/whatsup-at-service-hub



SEE AND UNDERSTAND

Get a better overview with CPOL3 for wiring tests.

Wiring errors commonly cause protection system failures in power supply systems. Testing the wiring during commissioning and after maintenance work is essential for preventing the danger that wiring errors can cause. This is a time-consuming process, as transformer wiring, trip signals, interlocks, remote control technology, and much more soon add up to hundreds of connections within installations. CPOL2 already provides a tried-and-tested, flexible procedure for testing transformer wiring, which – in contrast to the frequently used “battery method” – does not magnetize current transformers due to the DC-free saw-tooth signal.

However, as the trend toward more and more protection and remote-control technology continues, the complexity of wiring and challenges are rising along with it. We have developed our CPOL3 polarity checker to assist you in these areas. Like the CPOL2, the device can detect saw-tooth polarity test signals, and now, it can also detect AC and DC signals. Furthermore, CPOL3 even has some additional new features that surpass the proven functionality of its predecessor.



Indication when the test signal polarity is correct



Indication when the test signal polarity is incorrect

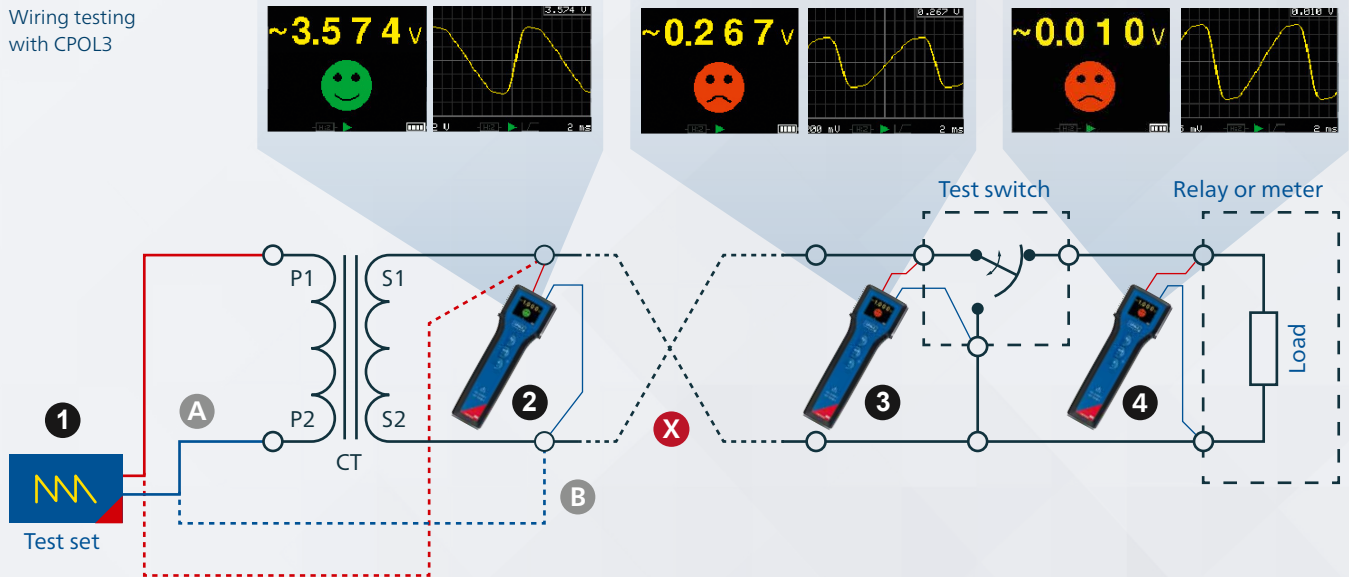


“Oscilloscope” mode for displaying the signal waveform



Spectrum mode (FFT) for detecting coupled signals

Wiring testing with CPOL3



New features

- › Displays the True RMS voltage as well as the polarity
- › "Oscilloscope" mode for displaying the signal waveform
- › Mode with low input impedance (LoZ) to suppress coupled signals
- › Viewing angle independent OLED display with high contrast for optimum readability
- › CPOL3 already displays phase information for future testing software

Highly versatile

You can combine several aspects of a wiring test using CPOL3 in conjunction with one of our test sets, such as COMPANO 100, CMC 353, or CMC 356:

- 1 During the test, introduce a saw-tooth test signal on the primary side (A) or the secondary side (B) of the current or voltage transformer. Primary injection is possible as current and voltage transformers transfer this signal waveform.
- 2 If the polarity is correct, the CPOL3 displays a green happy face. You can also display the signal in "oscilloscope" mode, and you will then see a saw tooth that quickly rises and slowly falls.
- X At this position on the secondary side, there is a wiring error.

- 3 The wiring error causes a polarity reversal, and CPOL3 displays a sad red face. You can also recognize the incorrect polarity from the reversed signal in "oscilloscope" mode.
- 4 In addition to the polarity, CPOL3 also shows you the measured voltage on the display. The nearer the load the measurement is taken, the smaller the loop impedance and displayed voltage. This allows you to easily check the terminal assignment by comparing the voltage and roughly determining the load.

Don't miss out!

Combining polarity checks with additional information by measuring the voltage and displaying the signals is an effective way of detecting the most common wiring errors. It will shorten your testing time while increasing the safety of your installation. ■

FIND OUT MORE ABOUT
THE CPOL3 HERE

omicronenergy.com/cpol3



OUR CYBERSECURITY SYSTEM SHINES WITH DISTINCTION

OMICRON receives security certificate from the BSI.



The German Federal Office for Information Security (BSI) has awarded our intrusion detection system StationGuard with the Fixed-Time Cybersecurity Certification (BSZ). We are the first intrusion detection system to receive this certificate.

The BSZ certificate confirms the security performance of StationGuard and its compliance with the BSI's high cyber security requirements. This milestone in intrusion detection confirms security performance of our system in compliance with all regulatory safety requirements.

What does the BSI IT Security Certificate mean for our customers?

Customers worldwide can rely on the highest quality and security of our solution. StationGuard fulfils the security functions required by the BSI, which have been confirmed by four test activities based on the planned procedure:

- › Testing of installation documentation
- › Conformance testing
- › Penetration testing
- › Evaluation of the implementation of cryptographic algorithms.

We know that every network is unique, so we work closely with our customers to provide customized solutions and increase cybersecurity. Cybersecurity can only be achieved through highly effective vulnerability management and accurate risk assessments.

Effective intrusion detection and management: StationGuard and GridOps set new standards

Regardless of the BSZ certificate, we continue to optimize our solutions to meet the needs of the energy industry. For example, StationGuard's add-on GridOps provides you with an optimal management interface for the StationGuard sensors in the grid, allowing you to collect and immediately analyze all the data provided. At a functional level, this means:

› StationGuard

The StationGuard IDS collects detailed data from each piece of equipment. The innovative allow-list system provides prompt and precise intrusion detection, reduces false alarms, and ensures the device is quickly ready for use. All alerts can be understood by OT and IT employees, facilitating smooth cooperation.

› GridOps

GridOps provides comprehensive asset inventory, an alarm dashboard, sensor management, centralized user management, and vulnerability management with extensive reporting. Customers only see the vulnerabilities relevant to them for successful vulnerability management and efficient responses. 🟡

LISTEN TO THE PODCAST

Interested in this topic?



How exactly does the StationGuard solution support the work of IT and OT experts? Do you know why effective vulnerability management and a comprehensive risk assessment are crucial for cybersecurity? In our podcast episode, „Vulnerability Management in Substations and Power Plants“ (ENU), you can learn more about this topic as well as how StationGuard supports the work of IT and OT experts. Scan the QR-Code or visit:

 omicron.energy/episode71-en



HOW TO VERIFY SUSPECTED INSULATION FAULTS IN POWER TRANSFORMERS

TEIAS, an electrical transmission utility in Türkiye, relies on MONTESTO 200 as part of its holistic approach to assessing the insulation condition of power transformers in its repair workshop and the field.

Introduction

Power transformers are one of the power grid's most important high-voltage (HV) assets. They are the key elements in generation, transmission, distribution networks, and industrial sites.

With the advancing

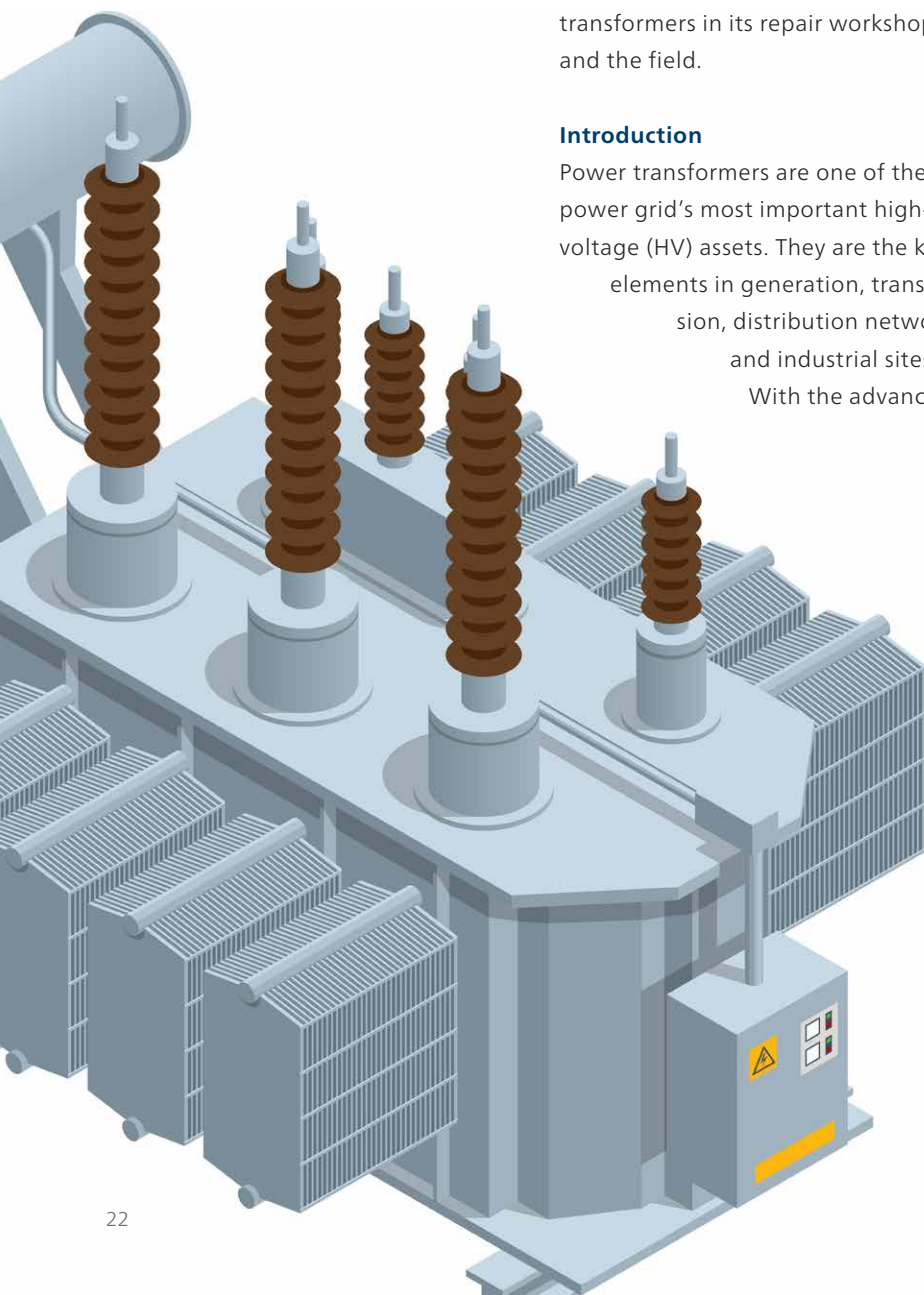
age of power transformers worldwide, it is vital to check their insulation condition by continuously assessing the health of various components to ensure reliability.

A power transformer is exposed to many stress factors during its life cycle due to environment and load conditions, high electrical field stress, mechanical vibrations, and chemical contamination. A lack of a regular diagnostic testing and maintenance plan can result in eventual undetected insulation faults that can shorten the expected service life of a power transformer.

Assessing insulation condition in power transformers

A holistic approach is generally adopted for the overall check of insulation condition in power transformers based on Dissolved Gas Analysis (DGA), various electrical tests, monitoring, and visual inspections.

DGA results from the insulating oil are used as a first alarm for any evidence of problems that can occur inside oil-filled power transformers. Abnormal levels of certain gasses can indicate potential problems, triggering additional investigations to identify and localize



developing faults using electrical testing, monitoring, and a direct visual inspection inside the transformer.

Advanced electrical testing and diagnostic tools, such as Dielectric Frequency Response (DFR) testing, Sweep Frequency Response Analysis (SFRA) testing, and Partial Discharge (PD) testing and monitoring, are now widely used to assess and diagnose the insulation condition of power transformers by detecting certain faults that conventional testing methods are unable to detect. In this article, we will focus on PD testing and monitoring.

Partial discharge testing on power transformers

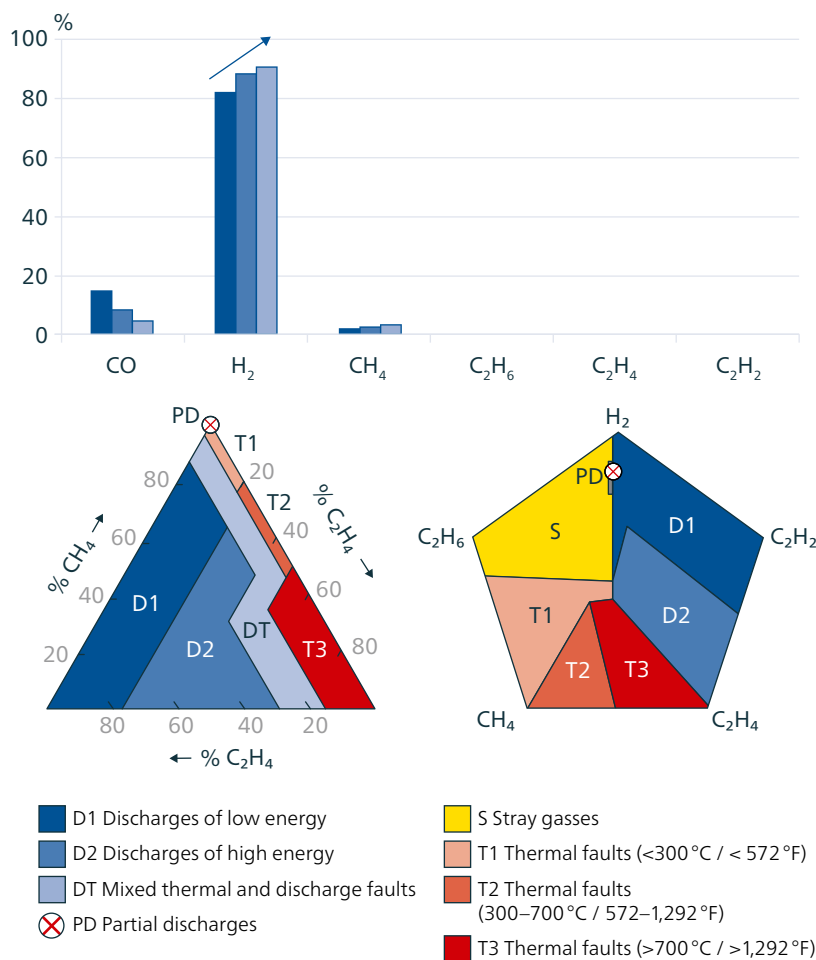
According to the IEC 60270 standard, a PD is a localized dielectric breakdown of a small portion of a solid or liquid electrical insulation system under high-voltage stress. PD is a reliable indication and an accelerator of fault development in electrical asset insulation. This is why PD measurement and monitoring play an important role in assessing insulation condition to maintain the health and reliability of electrical equipment, such as power transformers.

PD measurements on power transformers are initially performed at the factory as a quality control tool to assess transformer insulation condition according to specified acceptance criteria. During commissioning, PD measurements are performed to check the power transformers' installation condition after transport. During the power transformer's service life, PD measurements and monitoring are regularly performed for troubleshooting to detect and localize potential faults. ▶

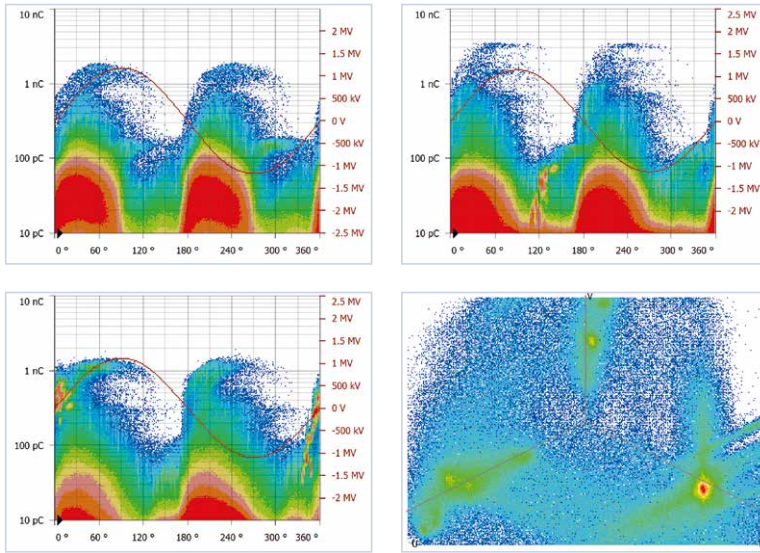
«After we opened the transformer for visual inspection, it became clear that our assumptions based on the PD test results were correct.»



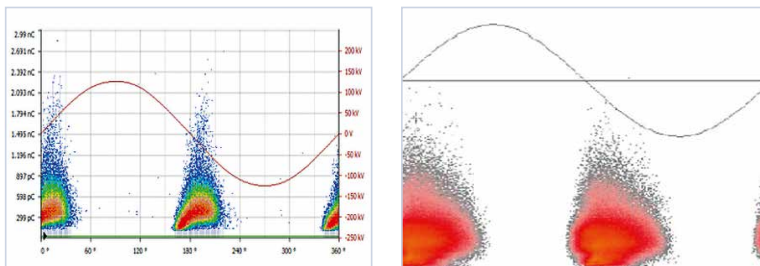
Mükremin Yanan,
Chief Engineer,
TEİAŞ Turkish Electricity
Transmission Corp.



Increasing hydrogen (H₂) levels were indicated after performing a DGA analysis on a 154/31.5 kV (100 MVA) 3-phase power transformer.



Different 3PARD diagrams were obtained that indicated various potential PD sources.



3PARD diagrams showing the possibility of voids in the insulation material before and after the vacuum was applied.

According to CIGRE 676, this PRPD pattern is very close to the one related to voids in glue.



Traces of carbonization were found on various components.

Many utilities worldwide have established maintenance programs based on periodic PD testing and monitoring of their power transformer fleets since PD is a reliable indication of aging and developing faults in the insulation. Corrective actions can be taken before a developing fault eventually causes the asset to fail.

PD testing, inspection, and repair of a 100 MVA transformer

I am the Chief Engineer responsible for field test evaluation and test method development at TEIAS Turkish Electricity Transmission Corp. My team and I have developed a holistic approach to condition assessments and a solid maintenance plan for our grid assets, particularly power transformers. If potential faults are detected in the field, the transformers are taken out of service and sent to our central workshop facility in Ankara, Türkiye. Medium and large power transformers are tested and diagnosed in our workshop's HV lab to determine if repairs and refurbishments are needed to return the transformers to reliable service.

In one case, our test engineers investigated a 154/31.5 kV (100 MVA) 3-phase power transformer, which has been in service since 1996. A DGA analysis initially performed on the transformer in the field displayed a continuous increase of hydrogen (H_2) and methane (CH_4) gasses, which indicate potential PD activity and damage to the insulation in the transformer.

Due to these increasing gas levels, we removed the transformer from the grid and sent it to our central workshop for further inspection and repair.

In our workshop's HV lab, our test engineers started by performing various electrical tests, including a DFR test, but no results were obtained to verify their suspicions of PD activity.

PD testing revealed various PD sources

As a next step, a series of PD tests were performed with OMICRON's MONTESTO 200 temporary PD monitoring system using the induced voltage method. The PD tests were done over extended periods of time at different central frequencies and bandwidths to obtain the best signal-to-noise ratio. The patterns obtained clearly indicated high PD activity from various PD sources.

Thanks to the 3PARD diagram (3-Phase-Amplitude-Relation-Diagram), which is integrated into the MONTESTO 200 monitoring software capabilities, our test engineers could see many clusters, indicating various potential PD sources in the transformer, which could be separated for individual analysis.

Analyzing different 3PARD clusters

When applying the 3PARD filters on some clusters displayed around the three phases, symmetrical discharges around the zero crossing characterized a predominant PRPD (Phase-Related PD) pattern. The shape of the pattern indicated it was probably related to voids in the insulation material, possibly in the oil. Still, even after applying the vacuum to remove the oil in the transformer tank, the same discharges remained with the same PRPD diagram, which means that the voids might be on or inside the solid insulation. On the other hand, according to CIGRE 676,

this PRPD diagram is very close to the one related to voids in glue.

Besides, another PD source could be seen very clearly with the 3PARD filtering, and it was most probably due to carbonization on the pressboard barrier – mostly around phase W. Still, it could also be seen in the other phases. Filtering other clusters revealed yet another type of PD related to floating metallic particles around phases U and V.

Visual inspection confirms PD testing results

Based on the PD test results, our test engineers decided to open the transformer for a visual inspection to identify suspected damaged components. After the transformer was opened, it became clear that our assumptions based on the PD test results were correct, and the extent of the damage was immediately apparent. After removing the oil from the tank, many copper dust particles deposited in different places inside the transformer were visible. This copper dust was likely the floating metallic particles suspected when the oil circulated.

Additionally, traces of carbonization were found in almost all the phases (HV coarse, HV fine, LV coarse) on the pressboards and wedges. In addition, our inspection team also found many traces of damaged and burned glue on the upper side of the coarse-tuning windings of phases B and C.

The transformer was then repaired in our workshop. All the damaged parts were replaced with new components and materials.

PD monitoring verifies the success of repairs

Additional PD tests were performed in our workshop's HV lab after the repairs were made, and no suspicious PD activity was detected. Once back in service, continuous on-site PD monitoring was performed for many months with the MONTESTO 200 device used in our repair workshop. No additional PD activity was recorded that indicated remaining or developing faults in the transformer. This was a verification to us that the repairs were successful. The transformer was back in reliable service. ■



Traces found of damaged and burned glue.

LEARN MORE ABOUT MONTESTO 200

 omicronenergy.com/montesto200



NO SHORTAGE OF SHORTAGES

Impact of the component crisis on the energy sector.



Whether you wanted to buy a new car, build a house, or get hold of a game console to fill the hours during the lockdowns – since at least the beginning of 2021, we have all been feeling the effects of the chip shortage on the global economy. The crisis has also impacted the energy sector. Limited availability, astronomical prices, and unreliable delivery times meant we faced challenges on a scale we had never seen before. Meanwhile, our

delivery times have long since returned to their pre-crisis levels. Below, we explain how we achieved this and what it means for future orders.

Causes and consequences of the component shortage

The causes of the component crisis were varied, and they still are. They can be partly attributed to the coronavirus pandemic and have also been influenced by other global and

socio-political events, leading to a complex situation.

- › Lockdowns severely restricted production in many areas.
- › The significant increase in demand for home entertainment and office equipment resulted in a massive demand for semiconductor components.
- › Passenger transport came to a standstill during the international

lockdowns, further restricting freight capacity and causing shipping costs to rise.

- › The conflict between Russia and Ukraine intensified supply chain challenges in specific sectors by restricting deliveries of metals, food, chemicals, and other raw materials.
- › The increasing popularity of electric cars is also affecting the availability of components, as these vehicles require considerably more electronic components than those with combustion engines.

The consequences were uncertain and unreliable delivery times and a price increase of over 400%. We were forced to obtain components via new channels, which – in addition to astronomical prices – also introduced a quality risk, resulting in additional quality assurance tests having to be performed for every delivery.

A sustainable approach to the shortage

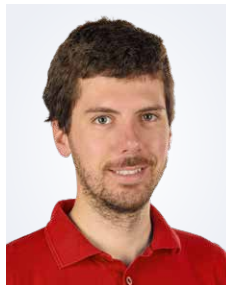
It was clear to us from the beginning that we had to meet this challenge with a long-term approach that would also deliver quick solutions, fulfill our customers' requirements, and guarantee consistent quality.

To meet these high demands, we established an interdisciplinary Shortfall Panel. The panel aimed to monitor the situation, make decisions about specific critical orders and tenders, enable additional delivery time optimization, and ensure prompt and seamless communication with our customers and sales partners.

Goals: reduce delivery times and ensure quality

The Shortfall Panel's objective was clear: keeping delivery times as short ▶

«It was clear that we needed quick yet reliable solutions, and they would only be possible with a high level of investment.»



Johannes Malin,
Shortfall-Panel Lead, OMICRON



as possible without compromising quality. Several measures were introduced for this purpose:

Boosting stock

The first and most obvious step was to stock up on all components and spare parts. We had a considerable advantage over many other companies in this respect, as we have longstanding partnerships with our electronic component distributors and often work directly with manufacturers. In addition, we procure a significant amount of our mechanical components and accessories from regional manufacturers, which to some extent limited the effect of global bottlenecks and transport problems.

We bought unavailable components from our distributors if they had delivery times that were too long for us in other buying markets, sometimes at much higher prices. These components underwent intensive quality testing before being used in series production, helping us remain in a position to supply our products.

At the same time, we invested in 21,000 m² (226,042.12 ft²) of additional warehousing space to create more storage capacity.

Order-specific needs assessment

However, despite increasing stock levels, even we could not avoid all the bottlenecks, which occasionally required us to modify delivery times and assess and prioritize orders. The Short-fall Panel developed a process that enabled us to work on special orders with a higher priority, such as emergencies following natural disasters or for system-relevant applications.

Seamless, transparent communication

Communication with our customers and sales partners regarding delivery times was just as crucial. Remaining in close contact with them enabled us to understand and respond to their individual needs and manage their expectations. This made it possible to provide realistic delivery estimates and keep our promises.

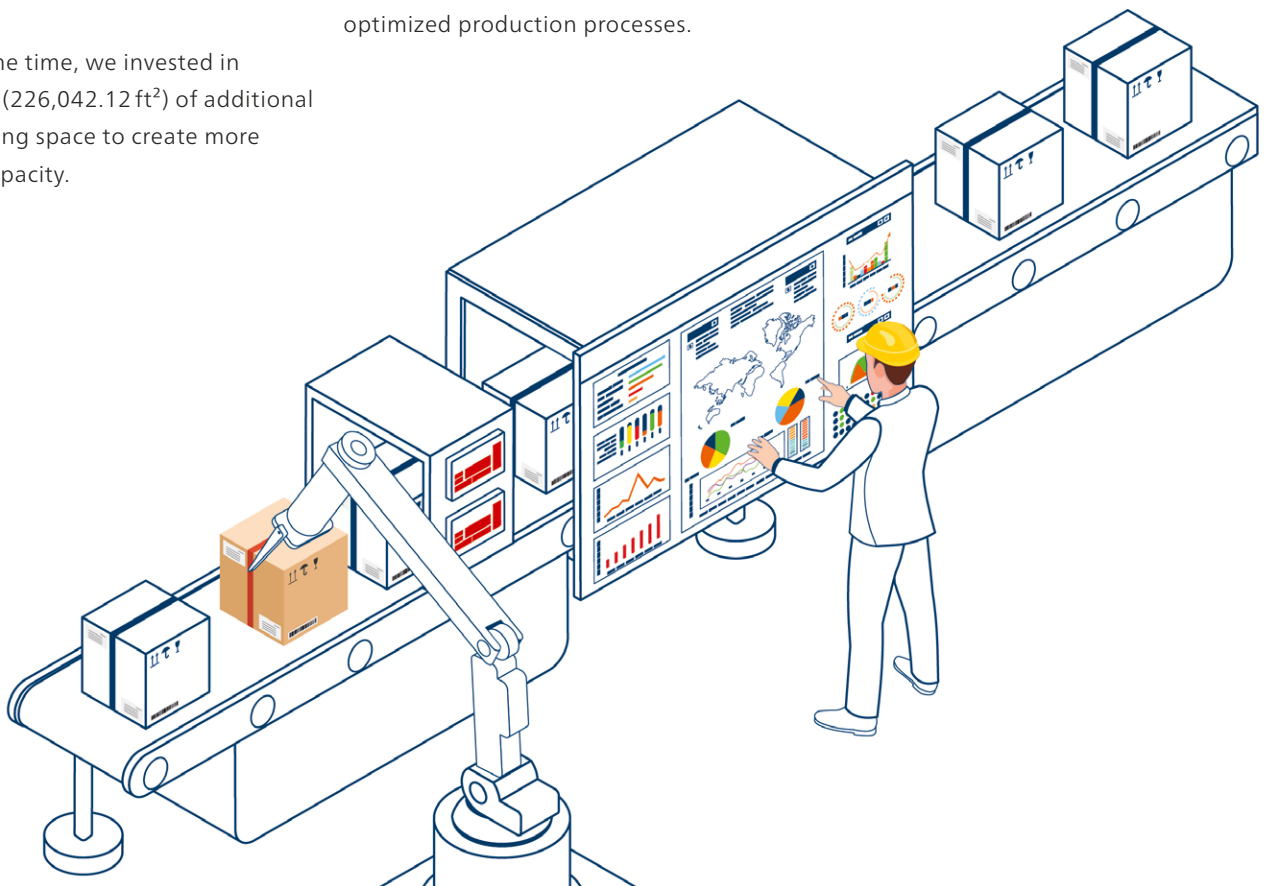
Long-term supply security

In addition to drastically shortening delivery times, we also wanted to minimize potential long-term delay issues. To this end, we analyzed and optimized production processes.

A dedicated team was assigned the task of looking for alternatives for components that were difficult to get hold of and proactively reworking our products, making it possible for us to use different components while achieving the same level of quality and functionality. More standard components found their way into our products, which should ensure availability even in the event of challenging market situations.

Successfully normalizing delivery times

Thanks to the joint effort of all the teams involved and significant investments in both time and money, delivery times have been steadily reduced, and over 95% of our products are now delivered within the pre-crisis time frame of four weeks or less. ■



WHAT'S NEW IN TEST UNIVERSE 4.40?

Greater scope for your tests.



Test Universe is the perfect tool for reliable and efficient parameter-based tests of protection relays. Our continuous product development has added new features in the latest version. For example, you now receive practical recommended actions in the event of connection problems, and it is easier to identify test sets and establish a connection.

What's more, it is now possible to connect to your favorite test set, even if it is offline or not within the network, opening up new possibilities, such as being able to prepare test plans for the team or working on several projects in parallel.

There are also significant improvements in terms of configuring your hardware. When switching between different test set types, you can transfer as many reusable parameters and settings as possible. This is a great time-saver as you no longer have to re-enter parameters and settings repeatedly. Further improvements make the tool even more intuitive to use.

Commissioning new protection relays without a Grandmaster Clock can be problematic, which is

why you can now simulate a Grandmaster Clock with your CMC or even use an inaccurate Grandmaster Clock for time synchronization. You can use this feature to commission IEDs with Sampled Values even if the intended Grandmaster Clock still needs to be installed.

Do you have to test residual voltages and currents regularly? Version 4.40 now offers the functionality you require in all relevant test modules so you can efficiently work with these variables using automated test procedures.

With these comprehensive improvements, the new version sets new standards in terms of user-friendliness, flexibility, and efficiency for parameter-based testing of protection relays. ■

You can find more information about Test Universe 4.40 here and download the new version for free.



 omiconenergy.com/testuniverse

CIRCUIT BREAKER TESTING AROUND THE WORLD

How are circuit breakers being tested on different continents?

In our podcast Energy Talks we have published a circuit breaker testing series in which experts from different regions discuss what is essential to their daily work.

USA



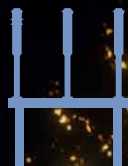
Our journey began in the **United States** with Charles Sweetser in Maine. Charles explained why dead tank circuit breakers are commonly used in HV levels and how they are usually tested. We also discussed the importance of motion tests and their difficulties with him. Additional challenges in North America include the influences of Current Transformers that are typically built-in and how to overcome their effects on measurement results. We also emphasized the importance of performing insulation tests with dead tank circuit breakers.



Germany



Our expedition took us across the Atlantic to Northern **Germany**, where we talked to Bastian Wölke from Westnetz GmbH. Dead tank circuit breakers are rarely seen; we discussed live tank circuit breakers, focusing on maintaining their vast fleet of MV circuit breakers. With 25 years of experience, Bastian has far-reaching insight into the most efficient testing procedures and trends from older circuit breakers as well as newer alternatives. We also had an in-depth discussion about the future of circuit breakers, how they might be tested, and the challenges of modern technologies.



Australia



After getting a European perspective, we crossed the globe to arrive in **Australia**, where we gained more insights from Florian Predl and Tibor Congo from Melbourne. Interestingly, there isn't a preferred type of circuit breaker in their area; dead tank and live tank circuit breakers are both commonly used, depending on the physical condition of the substation and the operators' personal preferences. We learned about a specific practice that allows dynamic resistance measurements to be performed on dead tank circuit breakers, and we looked into future trends like online testing and monitoring.



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 omicron.energy/CB-testing-around-the-world



United Arab Emirates



Following our discussions about different perspectives for breakers in air-insulated substations, we crossed the Indian Ocean searching for an expert on gas-insulated switch-gear (GIS) in **Dubai**. With his prior experience at a GIS factory, Anas Abdulkhader guided us through the reasons for the extensive use of GIS in his area and the challenges of testing them. Anas also emphasized the safe testing methods he employs that require both sides to be grounded. This is a significant challenge due to the small resistance of the enclosure, yet it's made possible by modern testing solutions.

Austria



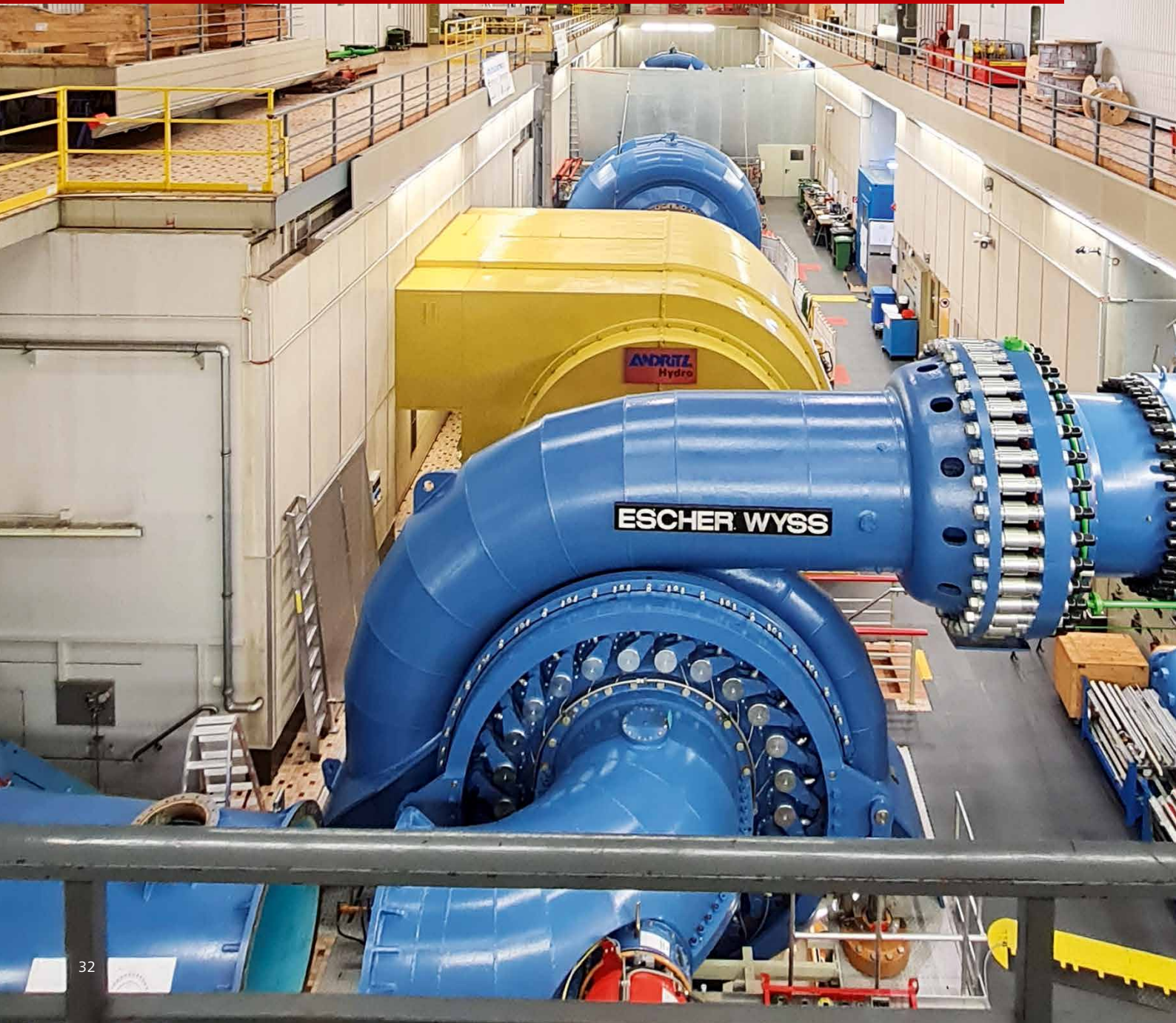
The final destination on our journey ended at OMICRON in Klaus, **Austria**, where we discussed the people behind OMICRON's circuit breaker testing device, CIBANO 500. OMICRON's product manager, Andreas Nenning, and former developer and current application engineer, Ari Tirroniemi, sat down with us to review the prior episodes and lessons they've learned from them. They discussed the common denominator in all the settings worldwide and the testing devices being used. We gained insights into the development of the CIBANO 500 and why it's the ideal system for efficient, worldwide circuit breaker testing. ■

GET MORE INFORMATION ABOUT CIBANO 500:

 omicronenergy.com/cibano500



A BLACKOUT IS FOLLOWED BY A BLACK START



What happens during a black start? The German transmission system operators Amprion and TransnetBW commissioned us to perform all measurements for a complete grid restoration test using 34 DANE0 devices.

Statements such as „We have to reckon with blackouts in the future“ and „The risk of a large-scale and long-lasting power outage in Europe is increasing“ are no longer seen as dubious attempts to manipulate public opinion; they now reflect the views of many experts. Various parties in the energy supply field, especially power plant and grid operators, are doing everything they can to ensure this scenario does not come to pass. Nevertheless, its likelihood is increasing. The reasons for this are complex: Both the type of generation, its spatial distribution, the ongoing transition from fossil fuels to electrical energy (electric cars, heat pumps, etc.), as well as system-unrelated factors, such as hacker attacks or armed conflicts, all represent potential triggers.

We have to accept the fact that one day, we might well experience a power outage. Does that mean we have to fear being without power for weeks on end? Definitely not. While a bit of preparation wouldn't hurt in our private sphere, it's good to know that specific procedures are in place in the event of an emergency. Specially trained engineers rehearse various scenarios and are ready to spring into action to restore our energy supply, like Amprion, TransnetBW, and Schluchseewerk AG staff, who have performed a grid restoration test with OMICRON's support. The entire test was monitored in real-time using DANE0 400 measurement devices, and all the results were recorded for subsequent analysis.

*«The challenges inherent in a test like this are considerable. In addition to demonstrating the black start capability of certain power plants, these same power plants must be able to energize a widely distributed testing network. **What is essential is that all the measurements, including communications, work perfectly and reliably on the day of the test.»***

Dr. Robert Dommerque, Amprion

The grid will need to be restored if there is a longer lasting and widespread outage in parts of the transmission and distribution grid due to a disturbance. Whenever this occurs, the grid has to be restored step-by-step. ENTSO-E (the European Network of Transmission System Operators for Electricity) maintains a series of Grid Codes that lay out framework conditions and duties for transmission system operators to restore the power grid. In addition to demonstrating that a grid restoration plan exists, they must verify its effectiveness and develop a practical routine by conducting regular simulations and field tests.

Power plants with black start capability are indispensable to any grid restoration concept. These plants must be able to be restarted autonomously without an external energy supply. These may include hydroelectric power plants or gas turbines, but in particular, appropriate pumped-storage plants, such as those used by Schluchseewerk AG.

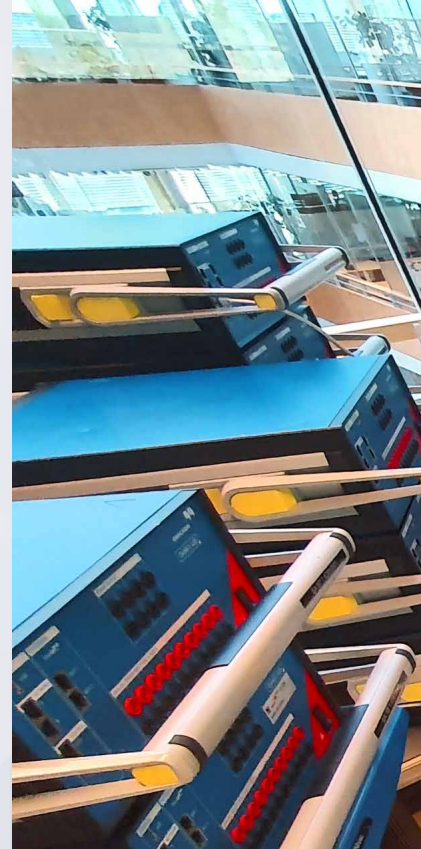
However, test processes like these are anything but an everyday occurrence, so they also offer a rare opportunity to test and investigate the behavior of assets under extreme operating conditions. By measuring the major nodes and assets in the trial grid extensively, it's ensured that relevant events won't go unnoticed, and the results can be used for in-depth scientific analysis. However, the requirements placed on the measurement system should not be underestimated. The system must:

- › be able to carry out extensive measurements on equipment distributed over many kilometers,
- › record readings from any number of measuring points at the same time,
- › permit all the measuring points to be monitored and controlled in real-time from a central operating station,
- › and deliver a high sampling rate for the acquisition of measurands.

The only solution on the market that satisfies all these requirements is our DANE0 400. The grid operators will not always have the necessary experience for complex measurements like these, and especially the number of measuring devices required. Therefore, we are proud to support Amprion and TransnetBW by working with them to make this ambitious project a reality. Like many projects of this kind, the lion's share of the effort went into detailed preparations, which took four years to complete due to various legal hurdles. OMICRON began participating in the project about two years before its realization. ▶



Live view of measured values in the DANEO Control



«DANEO 400 is a measurement instrument that completely satisfies our requirements. The reliable interaction of all the devices throughout the entire test setup and having the ability to control them all from a single operating station is a significant advantage for us. We repeatedly benefited from the rapid and detailed online analysis of the measured values during the test. Finally, the OMICRON team's professional support was another reason we opted for the DANEO 400. **All the technical queries we had before the test were answered quickly and reliably, and the support we received during the test played a significant role in bringing it to a successful conclusion.**»

Dr. Robert Dommerque, Amprion

The size of this interdisciplinary project meant that several different departments and technical sectors at Amprion and TransnetBW, Schluchseewerk AG, OMICRON, and the University of Duisburg-Essen needed to collaborate. Simulation and theory experts, various commercial and legal departments, power plant engineers, network, control, and communications specialists, and grid operation engineers were all involved, not to mention many others. One of the biggest headaches for project management was overseeing the coordination of everyone involved. On our end, it was about logistics, preparation, and equipment configuration. What was required was an unprecedented number of test sets (34 DANEO 400s) and accessories (CMGPS, current clamps, shunts, switches, etc.), in addition to calibrating and testing them. The fact that this was the largest project of this type in Germany became apparent when we had to ensure all the equipment was present – several hundred cables had to be counted and packed.

However, our involvement was more than just providing the measurement equipment. Our primary role was supervising and carrying out the measurements in real-time, and, guaranteeing that all the readings were recorded. In addition, we were also responsible for setting up the entire measurement system, including synchronizing the test sets. We also supplied, installed, and tested the central devices and accessories required for the communications



Preparing the measurement system at OMICRON in Klaus

network infrastructure in advance. After setting everything up on site for a week, the project team was ready to start the test.

At 8 am on the appointed day, the test network was disconnected from the rest of the grid and shut down. In addition to electrical quantities (voltages and currents), measurements taken during the black start included a multitude of machine parameters. These included various pressure readings, the position of the guide vanes, revolutions per minute, and numerous customer-specific measurements. The individual measurement points were spread across a total of seven sites, some of which were more than 100 km apart. These were time-synchronized via GPS for the measurement. This meant the measurement equipment could be controlled from the test control center, and measured values could be monitored in real-time. Approximately 110 GB of measurement data was recorded for further analysis. After about eight hours, the testing procedure was terminated on schedule, and the trial grid resumed regular operation.

The results of the test were more than satisfactory. The grid was restored without incident. Using such a comprehensive measurement range allowed us to identify areas that could be further optimized to enable the black start to function even more smoothly.

Together with the University of Duisburg-Essen, Amprion, and TransnetBW will subject the acquired data to further scientific analysis to extract even more helpful information. If a blackout occurs, there'll be no need to panic – a Prepper 101 course will not be necessary. ■



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ON SITE: OMICRON IN GEORGIA

Ivane Sachaleli from LTD Tranfiber-Service gives us his insight into the power sector.

LTD Tranfiber-Service – was founded in 1997, by its Director Ivane Sachaleli, in Tbilisi, Georgia. The company is accredited with ISO 17025: 2017/2018 and is one of the leading laboratories in Georgia in the field of electrical measurements and oil testing.

How is the energy grid structured?

Ivane Sachaleli: Georgia's electricity producers are categorized based on the following regulation goals:

- › Regulated power plants.
- › Semi-regulated power plants
(whose installed capacity is more than 65 MW).
- › Deregulated power plants, small capacity power plants
(with a project capacity of up to 15 MW).
- › Guaranteed capacity sources (thermal plants).

In the wholesale market, there are currently 106 electricity producers that demonstrate five thermal power stations, two regulators, eight partially deregulated, 14 deregulated, and 77 small capacity (deregulated) power plants.

What resources are being used to generate power?

The Georgian power system is supported by Hydro, Thermal and Wind power plants. Currently, the total installed capacity of the Georgian system is 4,596.4 MW. Namely:

- › **Hydro power plants – 3,394.3 MW:** Water reservoir hydro plants 1,993.1 MW; seasonal hydro plants 1,100.1 MW; small hydro plants (<15 MW) 301 MW.
- › **Thermal electric power plants – 1,181.4 MW:** Steam turbines 572.0 MW; CCGT 486.2 MW; gas turbine 110.0 MW; coal 13.2 MW.
- › **Renewable (except for water) – 20.7 MW:** Wind power plants is 20.7 MW.

What are the current hot topics for the energy supply market?

Georgia's energy sector is in an active development phase, and the country's goal is effectively harnessing a reservoir

of untapped renewable energy potential like hydro, wind, solar, and other energy-sufficient possibilities. Georgia has been generating additional electricity to meet the growing energy demand, especially when it comes to overcoming the winter deficit and reducing dependence on imported energy resources. Currently, there are 202 renewable energy projects that include 153 hydro, 18 wind, and 31 solar power plants in various stages of development. Georgia is among the top countries in the world for water resources per capita. Out of its approximately 26,060 rivers, 300 provide excellent opportunities for hydropower production, while currently, only 20–22% of total hydro potential is utilized.

What kind of challenges are your customers facing?

Georgia has implemented ambitious environmental and energy reforms over the years as part of its Association Agreement with the European Union and the European Energy Community. Nevertheless, Georgia still faces many challenges in transitioning to a more secure, sustainable, affordable energy future. Increasing public awareness about renewable energy production and its benefits and encouraging solar and wind energy use is vital. Furthermore, introducing and implementing digital technologies into the energy system creates new opportunities, allowing us to develop intelligent and interconnected networks.

Thank you for the interview. ■



Ivane Sachaleli,
Director and founder,
LTD Tranfiber-Service

 tranfiber-service.com



ABOUT GEORGIA

Capital: Tbilisi

Inhabitants: 3.736 million

Currency: GEORGIAN LARI (GEL)

Language: Georgian

National Dish: Khatchapur and Khinkali

National Drink: Georgia is the Cradle of Wine. Its culture has an 8,000-year history of wine making.

National Sport: Chidaoba (wrestling) is an ancient form of martial arts and sport, listed in UNESCO.

DOS AND DON'TS IN GEORGIA

- › **Enjoy the cultural traditions** and, of course, drink wine!
- › **Don't stay for only 1–2 days**, it won't be enough time.

Tbilisi city at sunrise

DETERMINING THE C-DIVIDER CAPACITANCES OF A CAPACITOR VOLTAGE TRANSFORMER

Developing a new measurement method

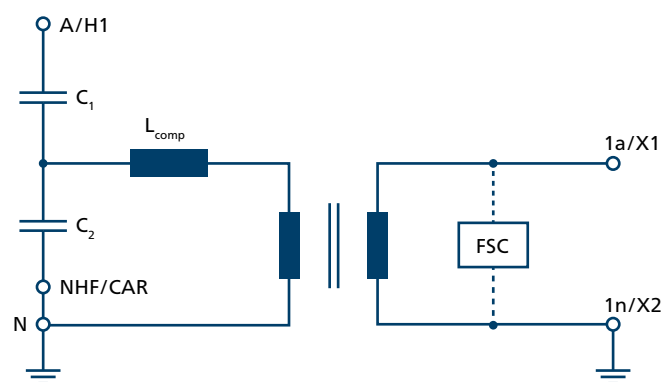
We were looking for a method to determine the individual capacitance values of a capacitive divider for Capacitor Voltage Transformers concerning accuracy and state determination, and we have recently met this goal. Here, we provide a short overview of the motivation behind developing and designing this new patented measurement method.

Voltage transformers come in an inductive and capacitive design. A Capacitor Voltage Transformer (CVT/CCVT = capacitor voltage transformer/coupling capacitor voltage transformer) is formed from a capacitive voltage divider, a compensation coil, and a medium-voltage transformer (Graphic 1). The voltage divider is often designed as a stack of smaller capacitor elements connected in series. Capacitance C_1 is usually smaller than capacitance C_2 . The power supply voltage (Graphic 1, connection A/ H1) is split into a

smaller voltage in the range of 8–20 kV at capacitance C_2 , which reduces the required degree of insulation of the inductive voltage transformer in the CVT. This design has been used for decades and is generally cheaper than pure inductive voltage transformers. CVTs are used from a power supply voltage of 40 kV and up, depending on the region.

The capacitances may change due to moisture entry, oil leakage, or aging, which, among other things, influences transmission accuracy. A survey in the CIGRE 394 brochure showed that aging CVTs are one of the leading causes of explosions. This is illustrated in image 1, which shows a voltage transformer. Therefore, it is essential to monitor the capacitance values of a CVT throughout its life cycle.

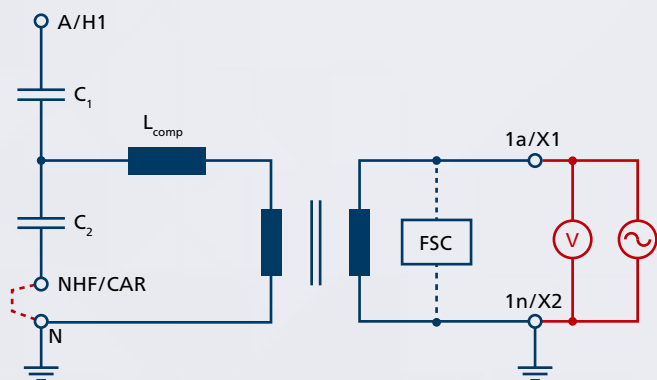
Voltage transformers worldwide have been effectively diagnosed using the VOTANO 100s model-based approach for years. VOTANO 100s modeling can produce highly accurate measurements without large equipment. However, the capacitance values of a CTs capacitive divider have always been a significant parameter that remains unsolved. However, the overall transfer ratio of a CVT can be determined when it comes to its capacitive voltage dividers; only the ratio of the two capacitances can be determined, not their values. The advantage of this new method is that the capacitance values can now be determined regardless of the CVT design. In the standard high-voltage test, certain preconditions related to the CVT design must be met to determine the individual capacitances. By combining the determination of the individual capacitances with the ►



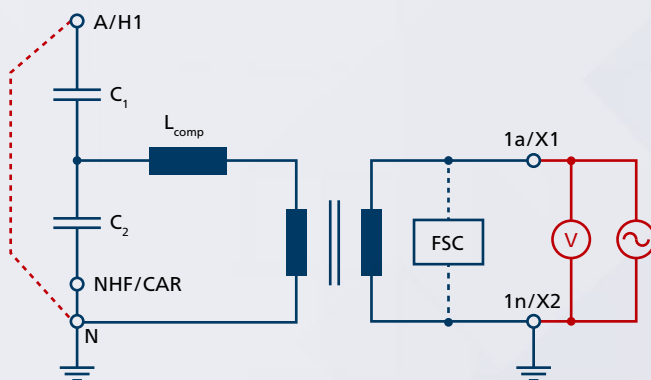
Graphic 1: CVT model







Graphic 2: Measurement setup for first short-circuit impedance.



Graphic 3: Measurement setup for second short-circuit impedance

accuracy measurement from VOTANO 100, more in-depth diagnoses of the equipment can now be made, as the state of the capacitive stack can also be determined. Determining the C_1 and C_2 values is essential, as capacitance C_1 is significantly smaller than C_2 . In other words, sometimes, a decline in the C_1 capacitance state may remain undetectable with conventional measurement methods. The new measurement method allows any change to capacitances C_1 and C_2 to be detected by comparing the measured capacitance values with the values of earlier measurements or with the manufacturer data for these values, regardless of the CVT design. Therefore, these types of comparison mea-

surements and the resulting trend curves represent another vital indicator for CVT conditions.

The model for CVTs has been improved continuously. Research has been carried out, measurements performed, and some scientific work has also been published. The studies showed, for example, that the capacitive ratio could also be determined using frequency measurements. This also inspired us to think of other measurement methods for determining the individual capacitance values and led us focus on short-circuit impedance measurements. Short-circuit impedance can be calculated from the current and voltage if you short circuit the primary side and feed current into the secondary side. Therefore, we determined that it would be possible to create an equation system using two separate short-circuit impedance measurements, which could then be solved mathematically.

In this measurement you can short circuit two points – the “Neutral High Frequency” terminal (NHF) and the high voltage. During the first measurement, NHF is grounded to determine the short-circuit impedance of C_2 for different frequencies (Graphic 2).

Then, a second measurement is performed in which the high-voltage part is also grounded so that C_1 is parallel to C_2 to determine the short-circuit impedance via the frequency (Graphic 3). The frequency measurement also provides a resonance frequency, which can be used to produce an equation system.

*«While the overall transfer ratio of a CVT can be determined when it comes to its capacitive voltage dividers; **only the ratio of the two capacitances can be determined, not their values.**»*



Image 1: Damaged voltage transformer after an explosion

In an electrotechnical sense, a CVT equates to a resonant circuit, which is why the theory of resonant circuits can be used to solve the equation system. The precise measurement method and mathematical procedure are patented and can be found in our IEEE paper, which we refer to in greater detail below.

Although the problem was theoretically solved, it took a lot of work to develop a functioning practical measurement. We started with a fundamental procedure using the first measurements and a simple calculation program. The initial results were encouraging, so the method was implemented in VOTANO 100. After the team fiddled about in the lab for hours, they understood the background better and were able to perform comparison measurements with a broad spectrum of test objects. Finally, we performed field tests at various manufacturers, including Mexico and Columbia, showing that our results are comparable with standard measurement methods. Then, we wrote an IEEE paper on this basis:

A new method for determining the C-divider capacitances of a Capacitor Voltage Transformer with frequency measurements (Bischof, Gopp, Atlas), 2023 IEEE PES GTD International Conference and Exposition (GTD)



ieeexplore.ieee.org/document/10261719

Developing this new measurement method, from the idea through theoretical considerations to performing functioning, practical measurements on a wide variety of test objects, was a very challenging undertaking. We want to thank everyone involved for their support, especially the companies who generously provided test objects for the field tests. ■



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A WORTHWHILE COMMITMENT

Why engaging within electrical engineering societies makes sense.

Power system professionals around the globe are working together collaboratively within non-profit electrical engineering societies. Whether it's Cigré, IEEE, or IEC – they all foster global knowledge sharing among electrical engineers to enable the provision of electricity for all – but does this engagement benefit the companies involved?

A few months ago, a colleague from a CIGRE working group started a new job. At one of our meetings, he complained that his new employer did not believe involving him in associations such as these was worthwhile for his company. Therefore, he may no longer be able to participate in our working groups.

Non-profit associations like CIGRE are geared towards the common good, and members must put cooperation above competition. What are the benefits of an association such as this? For society, the answer is simple. These associations develop global standards, identify best practices, and propose technical solutions long before most people even realize the need for change. One example from contemporary history is Oskar Oliven, a very active personality in the international electro-technical community. He had proposed a European 400 kV super-grid as early as 1930, about half a century before his vision became a reality (Image 1). A more recent example is a group of engineers around Alexander Apostolov, a colleague of

mine. Decades ago, his group recognized that a common communication standard could greatly benefit the electricity industry. Organizing themselves within several Working Groups, they defined all the aspects of IEC 61850. For example, Image 2 shows the members of working groups 10, 11, and 12, which defined the functional architecture and general requirements, the communication within and between unit and station levels, and the communication within and between process and unit levels, respectively. Today, this standard is changing power grids worldwide. If you are interested in the benefits of power system digitalization, I recommend reading Alex's book „IEC 61850: Digitizing the Electric Power Grid“ (ISBN-13: 978-1630818845).

However, what can we tell my CIGRE colleague's superior about the advantages for his company? In his book, Alex provides insights into the effort involved for members of a working group like this. The IEC 61850 working group met three times a year, alternating meetings were held at the working group member's companies, and care was taken to ensure that travel costs were balanced for everyone involved. During the meetings, the group worked on the content, and finally, a document was published in accordance with IEC rules. His description of the IEC working group's activities corresponds to what I know from CIGRE and IEEE. As far as corporate earnings are concerned, the primary advantage for me is that a better product can be brought to the market faster with more in-depth development within a shorter development period. The key to developing successful new technologies and innovative products is listening to users and prospects to understand their needs and requirements better. During the joint work on documents, a lot of networking with proven experts in the target markets occurs. This helps me better understand users' problems and identify new product applications. Therefore, it is clear that this kind of work benefits our customers, my company, and myself.

Recently, I met my CIGRE colleague again. He convinced his employer that this type of work makes sense, and he's going to continue working within our group. From my point of view, his employer has made a wise decision that clearly benefits his organization, his customers, and our entire industry. ■

Andreas Nenning,
Product Manager, OMICRON



Image 2: European 400 kV super-grid as proposed in 1930



Image 3: Members of working groups 10, 11, and 12

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