

OMICRON Magazine



CPOL3: A SMALL DEVICE PUTTING BIG
SMILES ON FACES ACROSS THE GLOBE



DEAR READERS,

As power system complexity increases, the opportunities to manage it with greater clarity, efficiency, and confidence are growing as well. This issue of OMICRON Magazine reveals how the right combination of advanced diagnostics, intuitive tools, and standardized approaches is helping turn today's challenges into measurable advantages.

We start with the foundations of rotating machine reliability. As industries increasingly adopt condition-based maintenance strategies, truly understanding the condition of stator winding insulation is more critical than ever. From quick integrity checks, such as insulation resistance, to advanced diagnostics, such as partial discharge testing, a structured testing approach provides early insights into aging and defects – the result: better risk assessment, optimized maintenance planning, and fewer unexpected outages. Outlining key tests and what they reveal about machine health is another approach this article explores in greater detail.

Efficiency in the field is just as important as depth in diagnostics, and that's what our next story explores on page 6. The CPOL3 shows how using powerful technology can also be simple. With clear visual feedback, high measurement accuracy, and versatile applications, it streamlines wiring tests and polarity checks – reducing effort while increasing confidence. Real-world experiences highlight how intuitive design and smart functionality can significantly speed up workflows and even make complex testing scenarios easier to manage.

Turning toward the bigger picture, digitalization is reshaping substations and raising the stakes for getting things right from the start. Our next article introduces the "Rule of Ten", illustrating how error costs increase exponentially throughout a project's lifecycle. In IEC 61850-based environments, where communication issues can remain invisible until a failure occurs, standardized verification becomes essential. By implementing structured processes such as

Publisher

Responsible for content

Editorial team and implementation

Picture credits

E-mail for the editorial team

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

OMICRON electronics GmbH

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

OMICRON electronics GmbH, iStock.com (p. 4, 6–7, 9, 11, 13, 20, 22, 24, 29, 32–36, 38–42), AdobeStock (p. 30–31), Energienetze Steiermark GmbH (p. 9), E.DIS Netz GmbH (p. 10), ETMS-Tec GmbH (p. 13), Shutterstock (p. 18), K D Johnson, Inc. (p. 28), Amprion GmbH (p. 47–49), Elia Asset (p. 51)

magazine@omicronenergy.com

system verification reports, utilities can detect issues early, reduce risk, and ensure long-term system reliability. Read more on page 20.

All three of these perspectives share one message in common: greater visibility leads to better decisions. Whether identifying insulation weaknesses, simplifying field testing, or verifying digital systems, the ability to see clearly is essential for mastering the complexity of modern power systems.

We're already looking forward to returning in 2027 with fresh insights, new stories, and continued inspiration from across the industry.

Enjoy reading!

Yours sincerely,



Lia Thum

Editor in Chief, OMICRON Magazine

**«The ability to see clearly
is essential for mastering
the complexity of modern
power systems.»**

TABLE OF CONTENTS



6 CPOL3 unleashed

A small device putting big smiles on faces across the globe



14 Rotating machine tests and monitoring basics

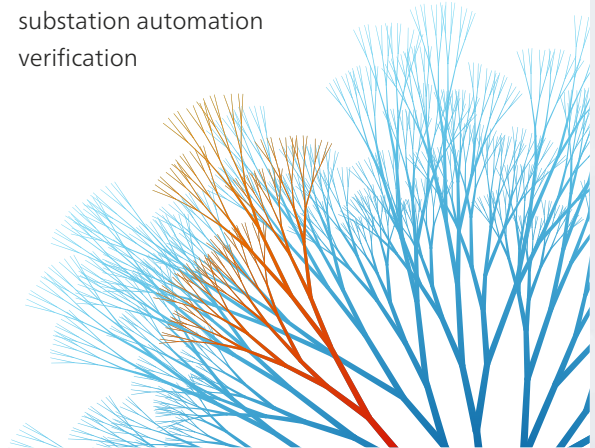


19 Ensuring switchgear reliability



20 The rule of ten

The benefit of standardizing substation automation verification



25 Learn more about PD measurement



26 Introducing the MBX2 for DANE0 Control

A high-performance network analyzer for fully digital IEC 61850 substations



28 On site: OMICRON in the U.S.

Michael Lenth from K D Johnson, Inc. shares his insights about the power sector with us.



30 Entering the future with roots and wings

Empowering power system stakeholders with eXplainable and causal AI



36 When operational technology is under attack

Why threat intelligence is essential for protection technology



38 Keeping the lights on



44 When safety and timing are no longer a trade-off

How both-sides grounding and DRM enable reliable HV CB testing.



46 ISIO 200 in practice: customer voices



52 What's going on



KNOWLEDGE



SUPPORT



INNOVATION



QUALITY

CPOL3 UNLEASHED

A small device putting big smiles on faces across the globe

The CPOL3 was launched 18 months ago as a tool for performing effective wiring tests and polarity checks. Its key feature is a clear and intuitive icon system that quickly indicates test results: when the

polarity is correct, a green smiley face appears on the display. The CPOL3 is being used in over 90 countries where it has been putting smiles on users' faces and their displays.



The CPOL3 is in use in all these countries around the world

SMILEYS, VALUES, AND SO MUCH MORE



A powerful combination

The CPOL3 is the perfect tool for wiring tests and becomes easily portable when combined with the COMPANO 100. When used with the CMC 500 and CMC Swift software, the CPOL3 delivers highly efficient multiphase tests. It is also compatible with the new CPX 200 for testing primary infeeds.



Fewer test steps

Sawtooth, alternating, and direct voltage signals are reliably detected and flexibly displayed. This allows several test tasks to be performed by a single device, including polarity checks, phase assignment, and voltage measurements for load determination.



Greater clarity

Detailed evaluations are made possible by voltage and current indications, an oscilloscope-like mode, and an optional frequency spectrum display. These features support clear and informed assessments, particularly in complex setups or during troubleshooting.



Reliable results

With its high accuracy and true RMS measurement capabilities, the CPOL3 guarantees dependable results. Factory calibration makes the device extremely precise, while its measurement range of up to 1,000 V AC and DC, and its ability to detect sawtooth signals from 100 μ V, enable accurate polarity checks and wiring tests.



Intuitive

Its compact dimensions, low weight, integrated magnet, and high-contrast OLED display facilitate use in substations. All this is complemented by a sophisticated operating concept and clear displays. Furthermore, an automatic shut-off feature protects against unintentional battery discharge. ▶

Further information

Would you like to find out more about performing measurements with the CPOL3? Scan the QR code for application examples and practical tips about CPOL3 wiring tests.



 omicronenergy.com/cpol3



UNDERSTANDING BUILDS TRUST!

Horst Paar studied electrical engineering at the Graz University of Technology and he has been working for the protection and technology team at grid operator Energienetze Steiermark since 2020. His role includes planning, testing, and commissioning medium and high voltage range protection systems. He is also responsible for performing conformity tests on power generation installations that comply with relevant standards and guidelines. Horst began regularly using the CPOL3 shortly after its market launch and offered to share his experiences with us.

Hello Horst, can you tell us how you have been using the CPOL3 and whether it's improved workflow?

Horst: I use the CPOL3 to test instrument transformer circuits and secondary wiring, including direction testing (polarity checks). The primary infeed allows me to test wiring all the way to the end device without interfering with the secondary transformer circuit. This makes it much easier to test difficult-to-access transformers because the terminals on the transformer's terminal board do not need to be opened.

Is there a situation you can recall where the CPOL3 was particularly helpful?

The CPOL3 has been especially helpful when I am testing gas-insulated switchgear because they are difficult to access and the wiring is almost impossible to trace by sight. The device quickly determines the correct grounding and supports reliable directional testing.

How do wiring tests with the CPOL3 differ from conventional methods?

I would estimate it is about a 40% efficiency increase. When I recently tested several medium-voltage branches, I was able to process them much faster, including running a complete check on all transformer circuits. The device also has many other potential uses, thanks to the voltage display during current transformer testing.

Are you able to rely on the CPOL3's polarity indicator and phase display?

Absolutely, ever since I used conventional measurements to verify the first installation results, I have had complete faith in the CPOL3's polarity and phase indications. I use the red/green indicator for polarity and the dot display for phase identification in my daily tests.

Are you also using the CPOL3's signal shape function?

I am not using it in the field yet, but the sawtooth signal displayed significantly increases understanding and confidence in the polarity indicator, which makes it very helpful for training.

Is there anything else you would like to tell us about the CPOL3?

In practice, we often rely on familiar and proven test methods, but it is definitely advantageous to be open to new approaches. The CPOL3 allows us to perform wiring tests much more efficiently, freeing up time for other tasks. ▶

«The CPOL3 has been especially helpful when I am testing gas-insulated switchgear because they are difficult to access and the wiring is almost impossible to trace by sight.»



Horst Paar,
Protection and Control Technology,
Energienetze Steiermark GmbH

ENERGIENETZE STEIERMARK

- › Head office: Graz (Austria)
- › Supplies almost the entire province of Styria with electricity and gas
- › Power grid covers over 32,000 km
- › Grid throughput of 7,652 GWh
- › Around 480,000 customers

CMC SWIFT

CMC Swift is the mobile testing software for CMC test sets. It enables convenient three-phase testing and remote control via a mobile device, allowing wiring tests to be carried out flexibly and efficiently when combined with the CPOL3. Scan the QR code now to find out more.



 omiconenergy.com/cmcsswift



WITH EXPERIENCE IN THE FIELD!



Jörg Dörner has been working at E.DIS Netz GmbH for many years and has extensive knowledge of protection and testing technology for energy installations. His daily routine includes testing current and voltage transformers and protective relays, which he often performs with the CPOL3 test set. During the following interview, he discussed his practical experience and shared insights about how he uses the device in his everyday work.

Hello Jörg, we are curious to know what your experience with the CPOL3 test set has been like and what advantages it has offered you.

Jörg: I mainly use it for polarity checks because the CPOL3 instantly determines whether current and voltage transformers are properly connected from the primary transformer to the protection relay. This information is extremely helpful, especially for both existing and external installations.

In the past, voltage drops could only be measured at many individual points. The CPOL3 allows me to feed a signal directly into the transformer and immediately assess the results in the protection relay. This significantly reduces my testing workload, making the process more efficient.

Can you give me an example from your daily working routine?

When we encountered repeated anomalies in the differential protection of a substation fed by wind energy, we used the CPOL3, and quickly determined that a current transformer in a medium-voltage cell was wired incorrectly. This wiring error had previously gone undetected and impaired the installation's protective behavior.

In your opinion, how has the CPOL3 improved compared with previous versions?

The CPOL3 is significantly more sensitive than the CPOL and CPOL2. This is mainly due to having the ability to combine the CPOL3 with a current clamp during testing, which wasn't possible with CPOL. With the increased sensitivity it gives us, we can reliably detect the smallest signals. In my opinion, the CPOL3 is the most powerful device on the market right now for this type of testing.

Which display do you usually use when you are working with the CPOL3?

When I am training someone, I first explain the polarity check using a sawtooth signal and show them the signal

«The CPOL3 is always in my tool bag, and I also use it regularly as a multimeter. Its interchangeable measuring tips, flexible test leads, and integrated magnet also make the device well-suited for use in control cabinets.»



Jörg Dörner,
Senior Secondary Technology Specialist,
E.DIS Netz GmbH

curve on the display that clearly demonstrates the principle behind this function. However, in practice, a quick glance at an evaluated result will usually suffice, because the green smiley face instantly lets you know that the polarity is correct. It is very simple and efficient.

Do you use the CPOL3's voltage indicator in addition to the polarity check?

The CPOL3 is always in my tool bag, and I also use it regularly as a multimeter. Its interchangeable measuring tips, flexible test leads, and integrated magnet also make the device well-suited for use in control cabinets. So, I do not need to carry around any additional measurement instruments.

In your opinion, how can the CPOL3 be improved in the future?

I think integrated resistance or continuity test features would be useful additions to the device. They would add to an already extensive range of functions, allowing it to completely replace separate multimeters in many applications. ▶



 omicronenergy.com/compano100

E.DIS NETZ GMBH

- › Head office: Fürstenwalde/Spree (Germany)
- › One of the largest regional distribution network operators in Germany
- › Over 2,000 employees and around 200 apprentices
- › Power grid (low, medium, and high voltage): 83,000 kilometers
- › Network customers: 1.5 million

COMPANO 100

Combining the COMPANO 100 and CPOL3 results in a powerful solution for single-phase wiring tests. Thanks to their low weight and mains-independent operation, testing equipment can be set up quickly and flexibly. Both devices are equipped with an integrated display that allows for easy operation directly on site.

Scan the QR code now to find out more.



WHAT IS THE STATUS OF THE FIRST CPOL3?

Michael Stobinski is an experienced electrical engineer and managing director at ETMS-TEC GmbH. He has a deep passion for the testing technology he uses daily across a wide range of energy supply installations. As the world's first owner of a CPOL3 he has been using the test set longer than anyone, which is why his practical insights are particularly valuable. He was kind enough to share some of his everyday testing experiences with us in the discussion below.

Hello Michael, what is your main area of expertise?

Michael: I am a service provider who primarily commissions and tests medium-voltage, secondary, and primary technology assets. Medium-voltage stations for EV charging infrastructure are one of my main fields. My responsibilities include commissioning complete stations, performing wiring tests and protection testing, assigning current and voltage transformers and conducting fault analyses.

Does your role as service provider require any specialized testing equipment?

Yes, my test equipment needs to be reliable, precise, and easy to use. Efficiency is crucial, and equipment needs to be capable of a quick set up that delivers clear results. Flexibility and portability are also vital because I work with a wide variety of installations. Detecting faults is crucial but being able to fully document them is as well. That is why having a clear display and the ability to evaluate signal shapes is extremely helpful.

What role does the CPOL3 play in your daily work?

I take the CPOL3 and COMPANO 100 with me on almost every assignment. I use the COMPANO 100 because it's battery-powered, and the CPOL3 for its versatile measurement options. This combination allows me to perform tests with minimal effort, especially when I am in installations

that are not in operation and lack a mains connection. These situations require me to focus on wiring and instrument transformer testing, and I use the CPOL3 to check polarity and the transformation ratio. The signal waveform display is very helpful for targeted troubleshooting.

Is there a practical example involving the CPOL3 that stands out in your mind?

Yes, when I was commissioning a medium-voltage substation in Gera, I noticed a clear anomaly in a voltage transformer's signal curve in the CPOL3's signal display. Instead of seeing the sawtooth signal I expected to, it showed me a significantly different signal shape, instantly making it clear that something was not normal. Following discussions with the manufacturer, they decided to conduct an on-site inspection, which led to their decision to replace the voltage transformer. This is just one example of the signal display clearly proving its worth during troubleshooting. If that potentially defective transformer had gone undetected, it could have led to considerable damage and downtime.

So, in summary, has the CPOL3 proven to be a worthy investment?

Yes, without a doubt. I use the CPOL3 for almost every job, and it replaces a classic multimeter for many tasks. I would like to be able to send measurement results directly to test sets like the COMPANO 100, which would significantly simplify documentation. All in all, I am extremely satisfied, and I have even ordered another CPOL3.

We want to thank our interviewees for their time and valuable feedback. We are delighted that the CPOL3 has been so well received, and we hope it will continue to bring smiles to satisfied users around the world. ■

«I take the CPOL3 and COMPANO 100 with me on almost every assignment. I use the COMPANO 100 because it's battery-powered, and the CPOL3 for its versatile measurement options.»



Michael Stobinski,
Electrical Engineer,
ETMS-Tec GmbH

ETMS-TEC GMBH

- › Location: Halle (Germany)
- › Provides services in the electrical power industry throughout Germany
- › Specializes in medium voltage and primary technology
- › Key areas include medium-voltage stations for EV charging infrastructure



Smiles all round during the handover of the first CPOL3

ROTATING MACHINE TESTS AND MONITORING BASICS

Electrical rotating machines range from high-voltage power generators that produce electrical power to medium-voltage motors that drive critical systems and processes for infrastructure, industry and manufacturing. Because these machines are so critical to our daily operations, a single failure can cause huge financial losses, stemming not only from physical damage to the machine but also from the high cost resulting from long periods of inactivity in power and industrial production.

Moving to condition-based maintenance

Driven by the shift from reactive to condition-based maintenance strategies, maintenance engineers have become increasingly involved in rotating machine tests over the past few decades. The latest solutions for rotating machine testing and monitoring help these engineers assess machine failure risks, so they can prioritize condition-based maintenance as early as possible. Perhaps you are one of them?

What causes rotating machine failure?

Several investigative international studies have proven that electrical insulation issues are one of the root causes of rotating machine failures. Periodic and continuous exposure to thermal, electrical, ambient and mechanical stress factors causes the stator winding insulation in rotating machines to degrade, age, and eventually fail. ▶

*«Several investigative international studies have proven that **electrical insulation issues are one of the root causes of rotating machine failures.**»*





Stator windings and stator core of a power generator. The rotor has been removed during routine maintenance.



FOUR RECOMMENDED ELECTRICAL TESTS

We recommend the following four offline electrical tests that focus on stator winding insulation. They provide you with a complete assessment of the stator winding insulation's integrity, aging, and contamination levels in a machine, which is why we consider them to be the most vital testing procedures.

1

DC insulation resistance (IR) and polarization index (PI)

These combined tests provide you with a quick stator winding integrity check.

- › Why it's important: It detects general problems immediately. It is sensitive to surface moisture and contamination, which affect insulation integrity.
- › What it tells you: If the IR value is low, the insulation is likely damp and/or dirty. The PI is the ratio of insulation resistance over 10 minutes vs. 1 minute. Based on international standards, the PI value should be 2 or higher in modern insulation systems.
- › The bottom line: It's the first line of defense for deciding if it's even safe to energize the machine for further testing.
- › Frequency: Annually or before startup after a long shutdown period.
- › Applicable standards: IEC 60034-27-4 and IEEE 43

2

Dissipation factor (tan delta) / power factor

This AC test assesses overall insulation quality and health.

- › Why it's important: In a perfect world, insulation acts like a pure capacitor. As it ages, it can become more resistive. Detecting increased insulation losses early supports condition-based maintenance decisions.
- › What it tells you: The dissipation/power factor test measures the ratio of resistive current to capacitive current (IR/IC). By assessing these dielectric losses in the insulation system, its overall condition and aging or contamination levels can be derived. A phase-to-phase comparison immediately shows you if the winding's parts have problems.
- › The bottom line: Dissipation/power factor measurements provide a quantitative indicator of insulation health, enabling early deterioration detection and preventing costly rotating electrical machine failures.
- › Frequency: Every 1 to 3 years
- › Applicable standards: IEEE 286 and IEC 60034-27-3

WHEN TO CONSIDER PD MONITORING

A standard offline PD test provides a timely snapshot of PD activity in rotating machines, but this activity can be highly volatile and change with temperature, load, and humidity over time. So rather than just providing a snapshot, online PD monitoring continuously trends PD activity during a machine's lifecycle. Applicable international standards for online PD monitoring are IEC 60034-27-2 and IEEE 1434. The benefits of implementing it include:

- › Correlation with operational stress: PD usually occurs when the machine is operating at a specific temperature and load condition. PD monitoring allows you to measure the effects of different operating conditions on PD activity continuously over time.
- › Trend analysis ("Rate of rise"): In PD analysis, the absolute value is often less important than the trend. A machine with high but stable PD can run for years; a machine with low but rapidly increasing PD indicates a developing problem that can lead to insulation failure.
- › Early failure warning: PD monitoring runs continuously online while the machine is operating. When predefined alert thresholds are exceeded, alarms are generated to notify the operator so that they can assess the risk and plan condition-based maintenance to prevent failures and unexpected outages. ▶

3 Overvoltage or HiPot test

This is a more aggressive assessment of the insulation's dielectric strength. Normally, the winding is stressed with a specific overvoltage for 1 minute. It can be done in AC or DC, but since the voltage distribution within the insulation is the same during operation, performing the test with AC is recommended.

- › Why it's important: The test applies voltages higher than the rated one to see how the insulation behaves under stress.
- › What it tells you: It looks for cracks, punctures, or localized weaknesses in the groundwall insulation. It verifies that the insulation can survive voltage stresses beyond normal operating levels without breaking down.
- › The bottom line: It confirms that the insulation can withstand its rated operating voltage with a safety margin.
- › Frequency: Every 1 to 3 years, combined with dissipation / power factor measurements.
- › Applicable standards: IEC 60034-1 and IEEE 95

4 Partial discharge (PD)

The PD measurement is the most advanced and predictive of the four tests. It detects tiny electrical sparks that occur inside the insulation and on its surface, which can damage it over time.

- › Why it's important: Most high-voltage failures don't happen instantly; they begin as microscopic voids or bubbles in the resin. PD measurements detect them at an early stage.
- › What it tells you: It identifies many different potential problems with the insulation system, including voids, delamination, and loose coils. Although PD degrades the insulation over time, this test can detect internal erosion before it appears in other measurements.
- › The bottom line: It's the ultimate early warning system for high-voltage machines (typically 6 kV and above).
- › Frequency: Every 1 to 3 years combined with dissipation / power factor measurements and HiPot tests.
- › Applicable standard: IEC 60034-27-1 (offline testing)

ADDITIONAL TESTING CONSIDERATIONS

The standard electrical tests and PD monitoring procedures we've recommended assess the stator winding's insulation condition. However, tests like the electromagnetic core imperfection detection (EL CID) test and sweep frequency response analysis (SFRA) are also vital because they inspect the mechanical and magnetic integrity of a machine's stator core and rotor.

Stator core low energy (EL CID) test

The stator core is made of thousands of thin steel laminations coated in varnish to prevent eddy currents. Stator core failure is just as detrimental to a machine as insulation failure.

- › What it does: It uses a low-level magnetic flux to scan the surface of the stator core.
- › Why it's important: If the varnish between laminations fails, due to vibration, overheating, or physical damage, local hot spots are formed. These hot spots can intensify during operation and result in significant machine damage.
- › What it tells you: It is a specialized maintenance test performed during major overhauls for detecting hot spots and assessing any related rotor damage.
- › Frequency: Typically, every 5 to 7 years, or whenever the rotor is removed for maintenance.

Sweep frequency response analysis (SFRA)

SFRA allows you to catch "hidden" structural damage during a major overhaul or after production.

- › What it does: It injects a sinusoidal voltage into the winding across a range of frequencies from Hz to MHz and measures the response. Any changes in the electrical network are detected.
- › What it tells you: It is a sensitive measurement mainly used for rotors and random wound stators that detects short circuits between winding turns.
- › Why it's important: Interturn short circuits are critical because they create localized circulating currents that generate excessive heat, leading to insulation breakdown and progressive winding damage. If left undetected, they can escalate, resulting in severe machine failure and costly downtime.
- › Frequency: Performed as a Factory Acceptance Test (FAT) for smaller machines, such as motors, and every 1 to 3 years on the rotors of larger machines during their service life.

Contact us for more information – We have a matching testing and monitoring solution for all the diagnostic practices mentioned in this article. Our solutions help you manage risk, ensure safety, and maintain long-term reliability of rotating machines. ■

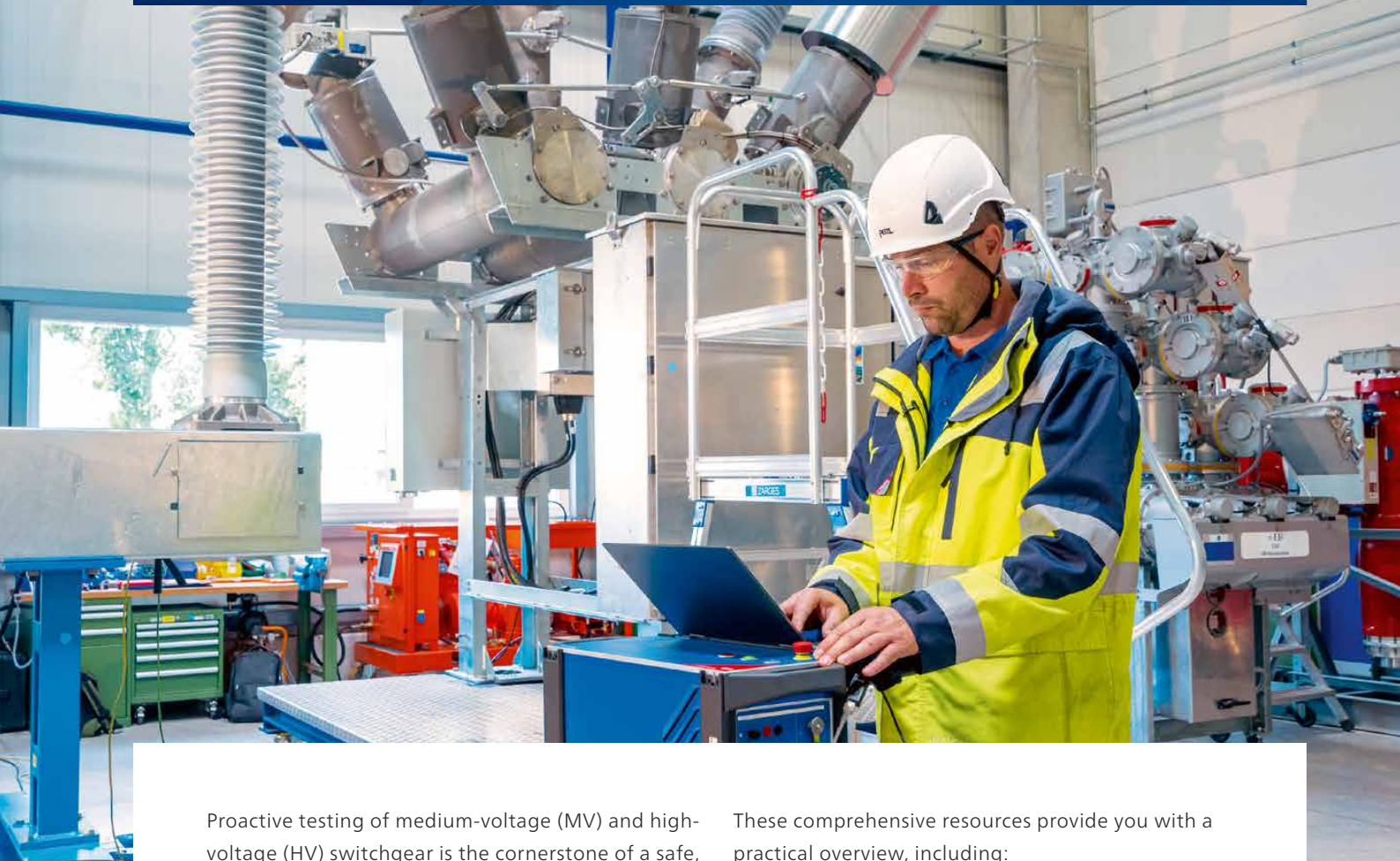
INTERESTED IN THIS TOPIC?

Scan the QR code to learn more in our new eBook, *The Basics of Rotating Machine Testing & Monitoring*. It offers you practical tips for getting started, including helpful videos that show you how to perform tests and interpret the measurement data.



 omicron.energy/basics-rotating-machines-testing

ENSURING SWITCHGEAR RELIABILITY



Proactive testing of medium-voltage (MV) and high-voltage (HV) switchgear is the cornerstone of a safe, reliable, and long-lasting power system.

The benefits of regular testing

Routine inspections do more than satisfy industry standards – they provide peace of mind. By detecting vulnerabilities early, regular testing prevents catastrophic failures, minimizes equipment damage, and eliminates costly unplanned downtime. The result is a safer environment and a more resilient electrical infrastructure.

Practical insights for beginners and experts

Whether you are just starting out or are a seasoned specialist, our two free testing guides will help streamline your workflow: “Diagnostic testing on medium-voltage switchgear” and “Diagnostic testing and monitoring on high-voltage switchgear”.

These comprehensive resources provide you with a practical overview, including:

- › **Recommended tests:** Detailed descriptions of essential procedures.
- › **Execution:** Step-by-step insights into how tests are performed.
- › **Solutions:** Recommended testing tools you can use to get the job done. ■

GET YOUR FREE SWITCH-
GEAR TESTING GUIDES

Simply scan the QR code:



 omicon.energy/switchgear-testing-brochures

THE RULE OF TEN

The benefit of standardizing
substation automation
verification



The power industry is currently undergoing a silent revolution. As we move away from the familiar world of hard-wired logic and toward decentralized, digital architectures, the very DNA of our substations is changing. Driven by the IEC 61850 standard, modern substation automation systems (SAS) offer us unprecedented flexibility and data transparency. But as any engineer who has spent a long night in a control room can tell you, this shift has also introduced a new layer of complexity.

In the old days, a wiring error was something you could see or measure with a simple multimeter. Today, our wiring consists of Ethernet packets – GOOSE, Sampled Values (SV), and MMS – traveling through fiber-optic networks. When these invisible wires fail, the consequences can be catastrophic. The question facing utilities today isn't just how to build these systems, but how to verify them effectively throughout their entire lifespan.

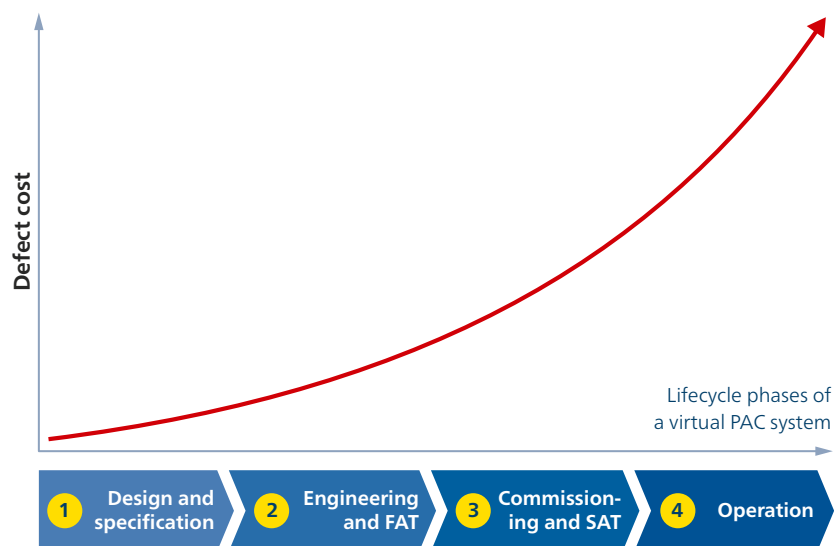
Solving this requires us to examine a management concept called Total Quality Management (TQM), which is becoming the golden rule for modern power systems: The Rule of Ten.

How much does a mistake cost?

The Rule of Ten is a stark metric for the external costs and logistical consequences of errors in an engineering project. The core premise is simple but harsh: The cost of fixing a mistake increases by a factor of ten at each major hand-off point in the project lifecycle.

If we apply this to substation automation, we can see a clear trajectory of escalating risk.

«The core premise of the Rule of Ten is simple but harsh: The cost of fixing a mistake increases by a factor of ten at each major hand-off point in the project lifecycle.»



1 The one-dollar fix: specification and design

At its earliest stage, a substation only exists as a digital twin or a collection of substation configuration language (SCL) files. If an engineer sitting in an office identifies a duplicate IP address or a VLAN mismatch during a virtual consistency check, the cost to fix it is essentially zero. It's merely a matter of correcting a field in a software tool before a single piece of hardware is even ordered.

2 The ten-dollar fix: factory acceptance testing (FAT)

Once we move to the FAT stage, physical intelligent electronic devices (IEDs) are being energized in a laboratory. If that same IP conflict is discovered there, the fix is ten times more expensive. Witness testing must be halted, physical devices re-configured, files re-loaded, and hours of functional testing may be re-run while clients and contractors are watching the clock. ▶

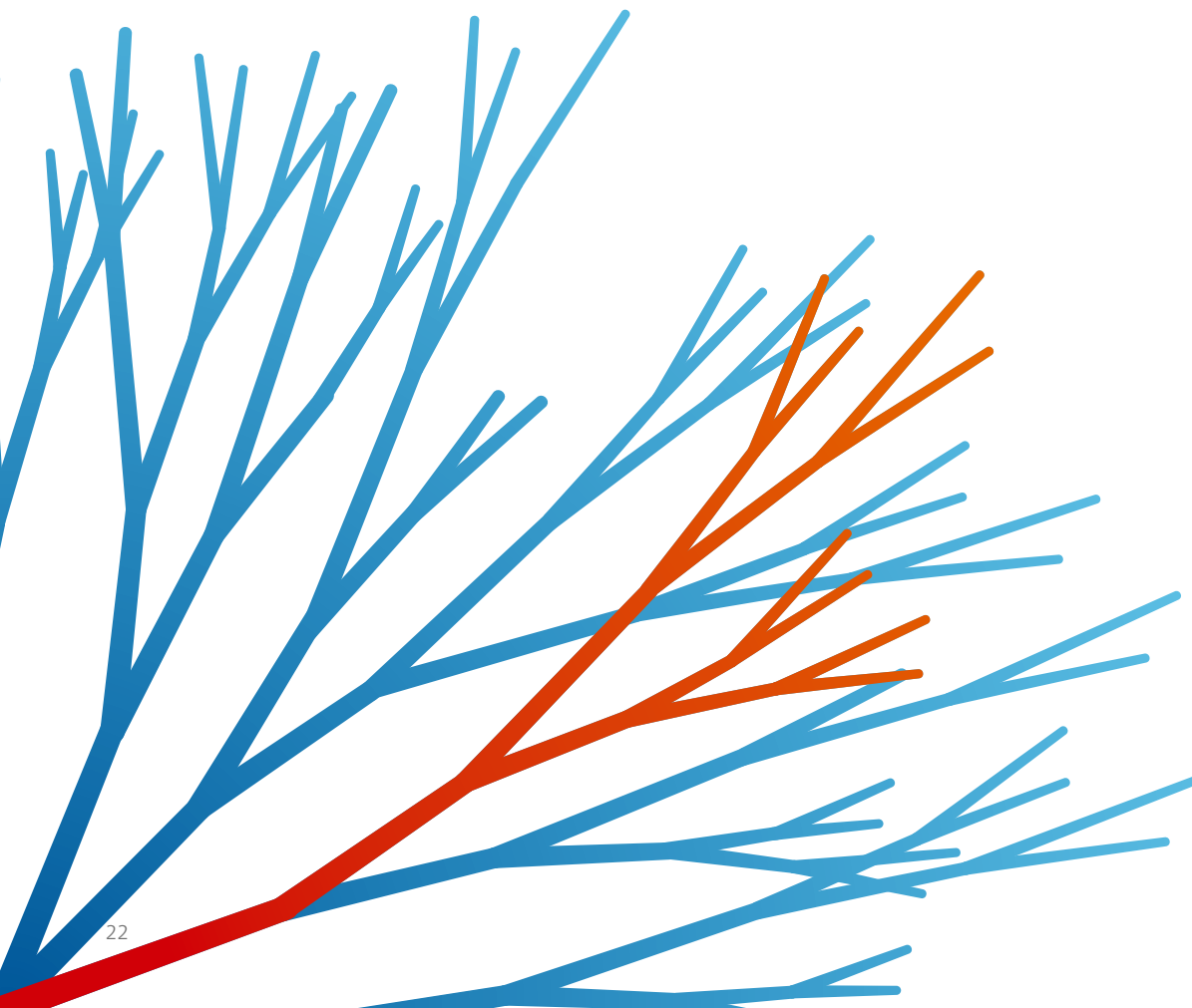
«We're proposing a shift in how we think about documentation to combat the Rule of Ten. Instead of producing a static PDF at the end of a project, we need a standardized system verification report (SVR).»

3 The hundred-dollar fix: site acceptance testing (SAT)

Now, imagine the error goes unnoticed until the equipment is at the substation site. This is the hundred-dollar fix. Finding a communication conflict during commissioning involves high-cost field labor, specialized equipment rentals, and the immense pressure of a limited outage window. If a configuration error delays the primary equipment from being energized, utilities may face liquidated damages – heavy fines for project delays – and the standby costs of an entire technical team.

4 The thousand-dollar (and beyond) catastrophe: operations

This is the scenario everyone wants to avoid. If a logic error – like an inverted trip signal or a failure in time synchronization – persists throughout a substation's lifecycle, the cost is no longer measured in working hours.



It's measured by unplanned grid outages, catastrophic damage to multi-million-dollar assets like power transformers, and potential safety risks to personnel. In this phase, the fix can easily cost thousands, if not millions.

Hunting for invisible errors

Why are these errors so difficult to spot? In an IEC 61850 environment, communication errors are often logical and invisible until they cause a system failure. Since IEC 61850 prioritizes the speed of critical protection messages, it bypasses the network (IP) and transport (TCP) layers of the open systems interconnection (OSI) model to deliver GOOSE messages directly to a MAC address in milliseconds. The downside is that if a Layer 2 error occurs, such as a VLAN mismatch, the message simply disappears. Therefore, an error message isn't sent back to the sender, and it becomes a black hole for critical data.

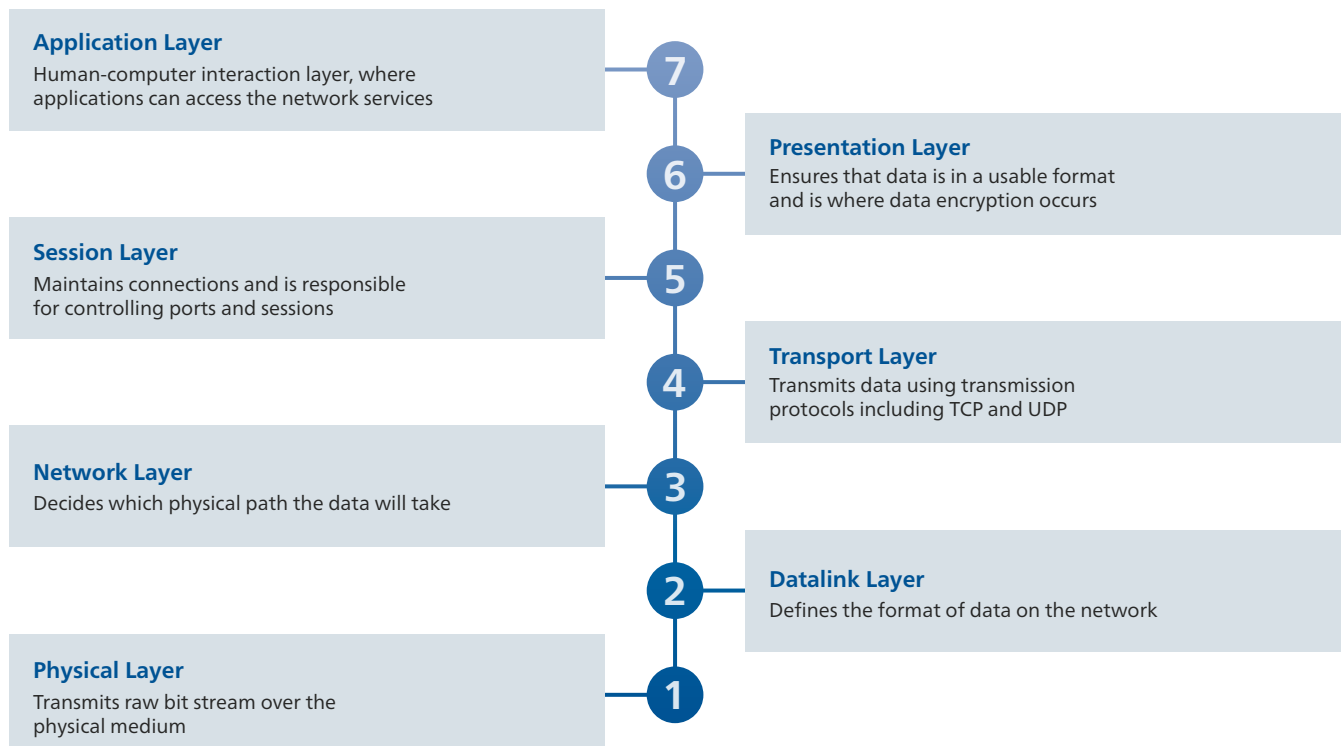
Common technical pitfalls include:

- › Duplicate IP and MAC addresses: These cause sporadic failures in MMS reporting or SNTP time synchronization. If two streams share a Multicast MAC address, IEDs may suffer from a buffer overflow or high CPU load as they try to process irrelevant data.
- › VLAN tagging mismatches: VLANs segregate traffic to keep Sampled Values from overwhelming the station bus. A single incorrect switch port configuration can prevent a breaker from tripping during a fault by blocking critical protection messages.
- › SCL inconsistencies: The substation configuration description (SCD) file is the master plan. If the version in the IED doesn't match the master file, communication will be blocked because the data set signatures don't match.

- › Time synchronization drifts: In modern systems using precision time protocol (PTP), accuracy is measured in sub-microseconds. PTP is essential for process bus applications; a deviation of just a few microseconds can lead to incorrect differential protection calculations and catastrophic false trips.

A living system verification report (SVR)

We're proposing a shift in how we think about documentation to combat the Rule of Ten. Instead of producing a static PDF at the end of a project, we need a standardized system verification report (SVR). This is a digital thread that tracks a substation's integrity from conception to decommission. ▶



Open systems interconnection (OSI) model

By standardizing SVR creation across four critical phases, we can identify errors while they're still one-dollar fixes.

Phase 1: Office engineering (ROI phase)

The goal here is to ensure the SCD file's architectural stability before hardware is even involved. Standardized metrics should include SCL schema validation (ensuring syntax correctness) and an automated virtual address audit that scans the entire station for duplicate IP and MAC addresses.

Phase 2: Engineering FAT (performance phase)

In the lab, the SVR expands to include the communication network's performance. We must measure the transfer time for GOOSE messages to ensure they meet strict requirements (often <3 ms for trip signals) and document the recovery time for redundancy protocols like PRP and HSR. Doing this ensures that multi-vendor integration functions properly during simulated loads.

Phase 3: Commissioning SAT (physical phase)

The SVR can validate the physical layer once it's on-site. This includes standardized logging of fiber-optic signal integrity (optical power levels in dBm) and confirming that the PTP grandmaster clock is synchronized to UTC within 1 μ s. We also perform digital wire-checks – ensuring GOOSE messages and breaker operations function properly after a physical current injection.

Phase 4: Maintenance (golden baseline)

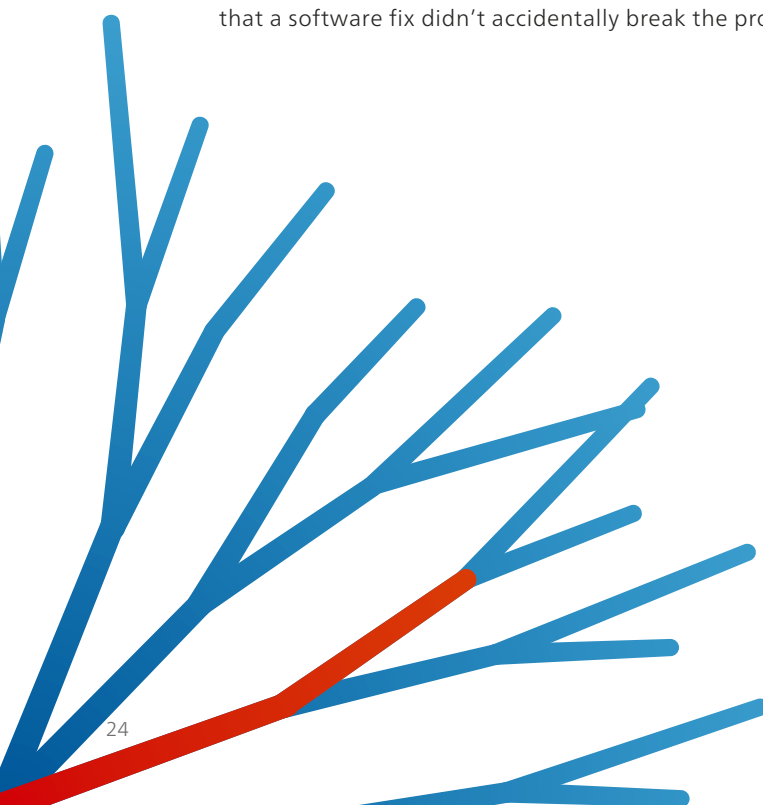
The SVR created during commissioning serves as the golden baseline for the next 20 to 30 years. Periodically comparing the live IED configuration with this baseline (fingerprinting), allows utilities to detect configuration drift. This comparison also becomes vital after security patches or firmware updates to ensure that a software fix didn't accidentally break the protection logic.

A call to action for utilities

Transitioning to digital substations is inevitable, but their economic sustainability depends on how we manage complexity. To fully realize the benefits of a smarter grid, we recommend three key steps:

1. Adopt a standardized template:
Establish a uniform SVR format to use for all project phases (design, FAT, SAT, and maintenance).
2. Integrate automation tools: Move away from manual documentation and toward tools capable of automated SCL parsing, live verification, and network traffic analysis to reduce human error.
3. Enforce early verification: Mandate a preliminary verification report at the end of the design phase to pinpoint logical errors before hardware procurement.

Applying the principles of the Rule of Ten ensures that the invisible wiring of our modern grid is robust, resilient, and – most importantly – verified. Standardizing our reporting isn't just a clerical task; it's vital for the future of power reliability. ■



**«Wouldn't you rather
discover those one-dollar
errors today instead
of facing a million-
dollar catastrophe
tomorrow?»**

LEARN MORE ABOUT PD MEASUREMENT



Did you know?

Partial discharge (PD) measurement provides you with the data necessary to transition from reactive to predictive or condition-based maintenance. Beyond mere detection, regular PD testing tracks the progression of insulation defects, allowing for maintenance intervention before degradation leads to catastrophic equipment failure.

Want to learn more?

Get free unlimited access to our four-part eBook series. This com-

prehensive collection guides you through the fundamentals of PD measurement, best practices for testing various electrical assets, and techniques for interpreting PD measurement results to assess insulation health accurately.

You can read them on your preferred device – computer, tablet, or smartphone. Each eBook also features integrated videos offering practical, hands-on tips for PD measurement. ■

GET THE EBOOKS

Simply scan the QR code:

 omicron.energy/get-pd-ebooks





INTRODUCING THE MBX2 FOR DANEO CONTROL

A high-performance network analyzer for
fully digital IEC 61850 substations

With the release of DANEO Control 6.00, we have reached an important milestone in the development of our DANEO solution. Alongside continued support for the DANEO 400, we are introducing a new device: the MBX2. This addition is our response to the ongoing transformation toward fully digital substations and the need for testing solutions capable of delivering a significantly higher level of performance.

The rapid evolution of substation automation systems, increasing system complexity, and growing data volume demand measurement and testing platforms that deliver

uncompromising performance and reliability. Software and test set must evolve together to meet these requirements. DANEO Control provides insight into electrical power system measurements and IEC 61850 network communication – in a single integrated software platform.

Why the MBX2?

The MBX2 device serves as a network analyzer optimized for fully digital substations. It offers sufficient performance and enables network interfaces to meet the requirements of modern communication infrastructures.



«The MBX2 delivers the performance necessary for reliably measuring and analyzing network traffic – even in large-scale, fully digital IEC 61850 substations.»



Matthias Wehinger,
Product Manager,
OMICRON

Unlike the hybrid DANE0 400 device, the MBX2 focuses exclusively on substation network communication. It provides a streamlined, purpose-built approach for measuring and recording signals and network traffic. Combined with DANE0 Control, the MBX2 forms a powerful solution that delivers deep insights into substation communication networks, which are essential during testing and troubleshooting.

Designed for large digital substations, the MBX2 features a high-performance platform and optimized network interfaces. These ensure fast, reliable access to IEC 61850 Sampled Values, GOOSE, and other substation network communication. Seamless integration with DANE0 Control 6.00 enables efficient configuration, flexible live observation, triggered recording, and intuitive analysis. This helps engineers gain clarity and confidence, even in complex digital environments.

Key benefits of DANE0 Control combined with MBX2 include:

- › Greater insight into the power system utilizing high-performance measurement with more phasor, RMS, frequency, and harmonic signals.
- › Reliable operation in large-scale digital substations, supporting a higher number of Sampled Value streams for measurement, recording and publishing.
- › Flexible network integration with additional ports and SFP transceiver options for copper and fiber connections.
- › A small, portable device that is also suitable for installation with DIN-rail mounting and DC power supply options.

The MBX2 expands the DANE0 portfolio with a hardware platform optimized for fully digital substations. It delivers focused performance, efficiency, and confidence for today's and tomorrow's power systems. ■

ON SITE: OMICRON IN THE U.S.

Michael Lenth from K D Johnson, Inc. shares his insights about the power sector with us.

K D Johnson, Inc. (KDJ) is a 100% employee-owned electrical manufacturer's rep agency serving Texas, Oklahoma, Colorado, Kansas, Missouri, Arkansas, Iowa, Illinois, Nebraska, and Louisiana. Founded by Dave Johnson, KDJ represents 15+ manufacturers with 30+ employee owners, providing sales and support for commercial, industrial, and utility customers.

How is the energy grid structured?

Michael Lenth: The U.S. electric grid delivers electricity through three layers: generation, transmission, and distribution. Power plants generate electricity, which is stepped up and moved long distances across high-voltage transmission lines (115–765 kV). Substations then reduce the voltage and send power through local distribution systems to homes and businesses, coordinated by regional operators and reliability standards.

What resources are being used to generate power?

Renewables such as solar, wind, hydro, and geothermal dominate global power generation. Coal still plays a key role but is declining due to renewable expansion and shifts to gas. Natural gas offers flexibility and reliability, while nuclear is seeing renewed interest through restarts and new projects, with oil contributing minimally. Storage and diverse sources support rising demands from data centers and electrification.

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

Electricity use continues to grow annually, fueled by data centers, EVs, and manufacturing, alongside nuclear energy resurgence and grid modernization aimed at improving reliability amid rapid load growth. Tariffs have proven to be an ongoing and fluid challenge, so remaining flexible

and adapting quickly is essential for customer-timeline assistance. Lastly, wildfire mitigation has also been a hot topic, with many utilities allocating significant budgets and resources towards it.

What kinds of challenges are your customers facing?

One of the major challenges both customers and manufacturers face is the upcoming deployment of 765 kV across various regions. Customers must source materials to build this infrastructure at voltage levels uncommon in the United States, while manufacturers are required to develop innovative product designs. Having to build out a utility's infrastructure at a lower voltage level to support 765 kV is an additional burden to their standard work plan.

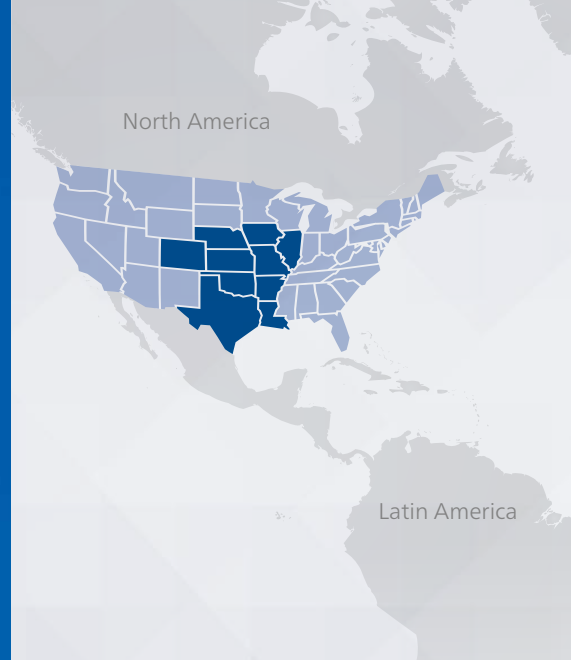
When looking towards the future, where do you see the biggest challenges in the power sector, and in general?

I think resources will be the biggest challenge for the foreseeable future. In addition to material needs, manpower is also a concern. Supporting utility growth projection requires qualified contractors and the frontline utility-workforce to constantly expand.

Thank you for the interview. ▀



Michael Lenth,
Senior Sales Engineer,
K D Johnson, Inc.
kdjinc.com



FACTS

Capital: Washington, D.C.

Inhabitants: ~334 million people

Currency: United States Dollar (USD)

Language: English

National dish: Hamburger

National drink: Coffee

National sport: Baseball

DOS AND DON'TS IN THE U.S.

- › Be **punctual**.
- › **Shake hands**.
- › Use **polite language**.
- › Follow **laws and rules**.
- › Make **eye contact**.
- › Respect **personal space and don't overstep** personal boundaries.
- › **Don't assume** everyone celebrates the same holidays.
- › **Don't discuss** sensitive topics casually.
- › **Don't ignore** tipping norms and **tip appropriately**.
- › **Don't be overly loud** in public spaces.

Capitol Building, Washington, D.C.

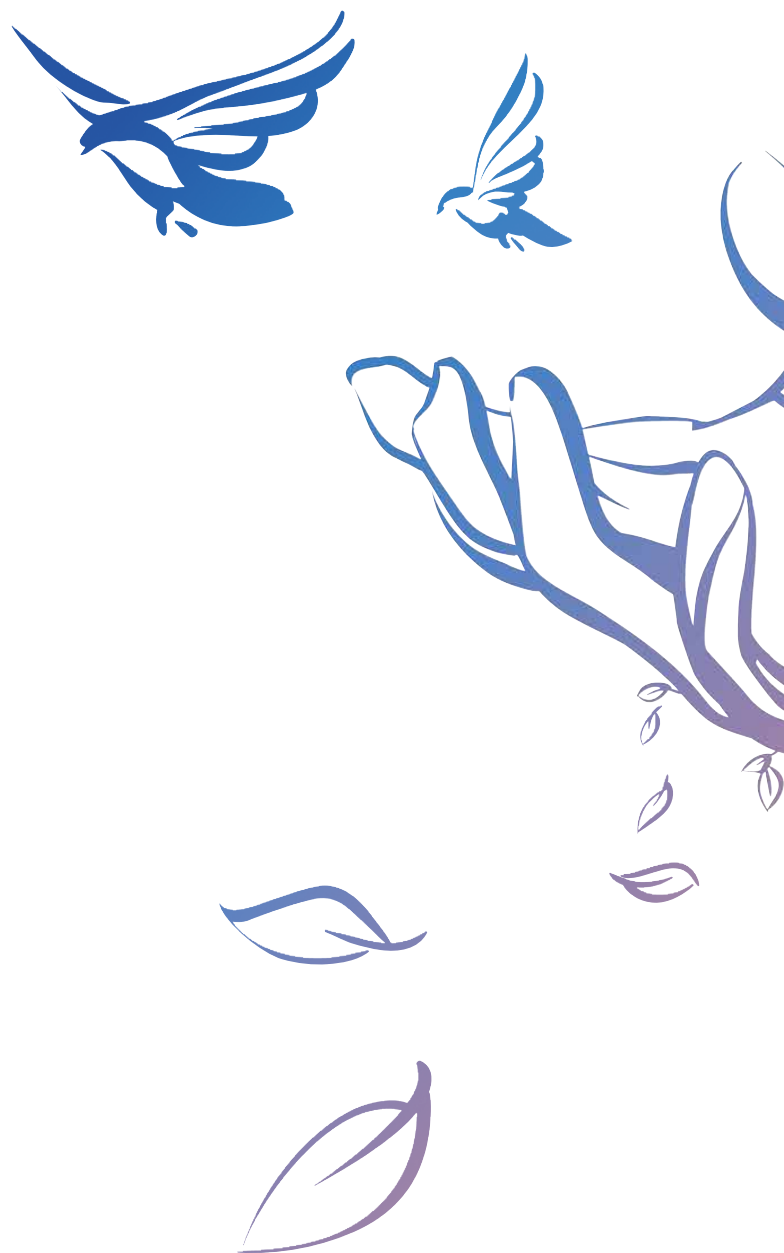
ENTERING THE FUTURE WITH ROOTS AND WINGS

Empowering power system stakeholders with eXplainable and causal AI

What does parenting have in common with building AI systems? At first glance, they may seem unrelated – yet both require roots for trust, and wings for empowerment. In the following conversation, Bertram Taetz and Rehana Mubarak-Aberer – co-authors of a PACWorld Conference 2025 contribution and parents themselves – explore how these shared principles can shape the design of more transparent and trustworthy AI, particularly for informed decision-making in safety-critical systems.

Rehana Mubarak-Aberer: Bertram, when I look at your research in human motion analysis for health care applications, I recognize a common core challenge in applying AI to health care and power systems. A model's usefulness not only hinges on the accuracy of its reasoning, but also on its eligibility in both safety-critical scenarios. However, most high-performance AI systems are opaque and function as "black boxes".

Given the "black box" nature of most high-performance AI systems and the demand for "trustworthy AI" in policy frameworks such as the EU AI Act, the OECD AI Principles, and the NIST AI Risk Management Framework, how can we bridge theoretical or normative trust expectations with actual practical implementation methods?



«While deterministic systems can be certified and tested under clearly defined conditions, **probabilistic and «black box» AI system behavior can change due to retraining, data drift, or updates.»**

Bertram Taetz (Prof. Dr. rer. nat.),
Professor of Data Science and Artificial Intelligence,
IU International University of Applied Sciences, Erfurt, Germany

Bertram Taetz: This question is not trivial at all, but before asking whether we can trust AI systems, we need to define what “trust” means to humans. From a psychosocial perspective, for instance, the concept of *Urvertrauen* (basic trust) coined by Erik Erikson refers to the early developmental experience of trust that children form when caregivers consistently meet their needs. Children benefit from basic trust to grow, develop, and build resilience that helps them cope with an unpredictable world.

Rehana: As a parent, I could not agree more ... and as we get older, trust is regularly established, extended, and negotiated. Various definitions note that when we trust someone, we acknowledge our vulnerability and expect them to act in our best interest. If we explore notions of trust in professional scenarios, such as consulting a doctor ... what is it that makes us trust them, their diagnoses and their recommendations? If we call AI “trustworthy”, do we risk violating users’ trust with misleading anthropomorphic expectations?

Bertram: Perhaps it is more pragmatic to distinguish between functional trust in a system’s reliability versus trust in the organization behind the system. But even functional trust is difficult to establish: While deterministic systems can be certified and tested under clearly defined conditions, probabilistic and “black box” AI system behavior can change due to retraining, data drift, or updates. As a result, ensuring true empowerment through AI systems requires new, additional methods – such as explainability. You conducted a PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses)-based review of 178 peer-reviewed papers published between 2014 and 2024. You focused on publications that apply methods for increasing the explainability of time series-based AI models in power systems. Can you summarize your main research challenges? ▶



EXPLAINABLE AI (XAI) FOR TIME SERIES IN POWER SYSTEMS

Rehana: The concept of “explainability” itself is a fundamental issue. While evaluation metrics can be used to assess the performance of AI systems by comparing predictions against ground truth, explainability still lacks a universal definition. This is the basis of the XAI research field.

Diverse methodological approaches are another key challenge. Data range from field measurements to simulations and public benchmarks, with varying time series resolution and volume. Pre-processing steps are inconsistently reported, and different base models are paired with different explainability methods.

Additionally, XAI research faces a critical gap: a lack of user-centric evaluation. Few studies assess explanatory power based on stakeholder feedback from grid operators, engineers, or regulators.

These combined factors make it difficult to compare XAI methods and assess their real-world value.

Bertram: Which major trends have you found?

Rehana: The review revealed that since 2020, there has been a sharp rise in research on XAI for time series in the energy sector. A substantial body of research aims to identify and interpret important features, using SHapley Additive exPlanations (SHAP) and attention mechanisms.

Let us look at how the SHAP algorithm works. Imagine we have a neural network that forecasts day-ahead load for a large urban area using time series data from temperature, humidity, calendar information, and photovoltaic (PV) generation. The model gives us a high load forecast for 6 PM tomorrow.

With SHAP, we can decompose this singular prediction into contributions: how much of that predicted peak is explained by the following variables:

- › Unusually high temperatures
- › A weekday rather than a Sunday
- › Low PV output during that hour
- › Unique events like a holiday

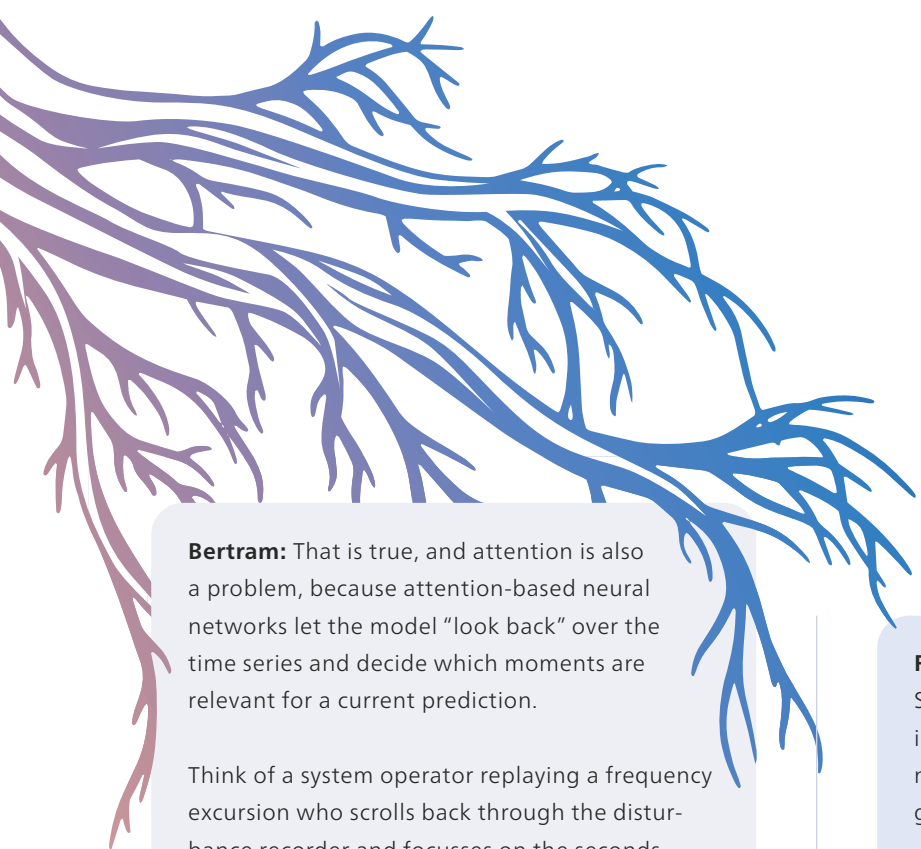
We can visualize this as a bar chart or a time-aligned plot, like we do when we inspect different components in a load decomposition. SHAP is rooted in game theory and offers insights into feature importance and variable interactions. However, the key takeaway for practitioners is that it tells you “how much each input moved the forecast up or down” at a given time step.

The downside is that SHAP often needs to run the model in the background multiple times, which can be computationally expensive, especially for a long time series or a very large model.



*«While evaluation metrics can be used to assess the performance of AI systems by comparing predictions against ground truth, **explainability still lacks a universal definition.**»*

Rehana Mubarak-Aberer (Dr.),
Marketing Expert, OMICRON



Bertram: That is true, and attention is also a problem, because attention-based neural networks let the model “look back” over the time series and decide which moments are relevant for a current prediction.

Think of a system operator replaying a frequency excursion who scrolls back through the disturbance recorder and focusses on the seconds where a large generator tripped and the primary control started reacting. Attention weights are a way for the model to highlight those “critical seconds” in the input time series.

We can visualize these weights as a heat map over time and features, which makes it easier to see, for example, that the model focuses strongly on ramping PV output and interconnector flows in the minutes before a predicted overload.

However, this comes at a cost. Since the attention mechanism compares multiple time points, its computational complexity scales roughly with the square of the sequence length. Therefore, processing very extensive histories can become quite expensive.

Rehana: And there is another crucial factor.

SHAP and the attention mechanism tell us which inputs move the model’s prediction, but they do not tell us if changing those inputs in the real grid will change the outcome.

Picture an afternoon heatwave where PV generation and load are high, and several corridor lines are close to their operational thermal limits. A forecasting model might learn that “high PV feed-in” is associated with future overloads and assign it high importance.

In reality, the overload risk might be mainly driven by air-conditioning load in a few specific feeders, while PV just happens to peak at the same hours. If we curtail PV based only on this correlation, we might reduce clean generation without significantly relieving the lines that matter.

In summary, all these methods share one limitation: they explain a correlation-based system output with another correlation-based explanation. ▶

RETURNING TO OUR ROOTS TO STRENGTHEN OUR WINGS: ENGINEERING AI TRUST FOR POWER SYSTEMS

Bertram: Exactly. Correlation can suggest relationships, but it does not explain them. In dynamic, high-stakes environments like power systems, relying solely on correlation-based explanations can lead to spurious conclusions.

This is where causal methods become essential. Instead of just asking “which variables are associated with overloads?”, we ask:

- › “If we intervene and curtail wind farm A by 10%, how does that change the probability of congestion in line 23?”
- › “If we raise day-ahead prices in zone B, how much will that actually reduce evening peak load, after accounting for weather and other factors?”

Techniques such as Causal Shapley values build on this “what if we intervene?” logic. They wrap your predictive model in a causal framework that distinguishes factors you can reasonably treat as causes (like setpoints, dispatched power, market prices) from those that are mostly background conditions (like weather). In addition to showing you which variables matter, they reveal how much actively changing those variables would alter the risk.

Rehana: Another concrete example would be a model that predicts the probability of congestion in a transmission corridor for the next hour. The input consists of time series from several wind and solar plants, the load from different areas, and interconnector flows.

A classical XAI method might simply tell us: “Wind farms A and B have the highest feature importance for this forecast.”

A causal explanation allows us to take the additional step of simulating counterfactual scenarios such as:

“What if we reduced wind farm A by 5% without changing anything else?”

In this case, we might see the congestion probability drop from 40% to 25%.

Doing the same for wind farm B, a 5% curtailment might only lower the risk to 38%, because most of its power flows through a different corridor.

This kind of explanation aligns much more directly with operational decision-making because it does not just tell dispatchers and planners which signals correlate with the problem. It tells them which levers are most effective.

Bertram: In more complex dynamic interactions, especially those found in oscillatory or highly coupled systems, extended forms of Granger causality and modern approaches like NeuroKoopman-based causal discovery or cross-mapping coherence can help identify directional influence between time series. However, the key message is that causal methods help us reason in terms of interventions and counterfactuals, which is much closer to how operators and planners think about control actions.

Rehana: Yes, the power systems domain has also shown a growing interest in hybrid models and recent advances in time series reasoning (TSR), physics-informed neural networks (PINNs), and reinforcement learning approaches that address this need. These emerging trends can offer more robust alternatives and help developers and stakeholders alike strengthen their decision making by identifying the root cause of a system’s output.

«Causal methods help us reason in terms of interventions and counterfactuals, which is much closer to how operators and planners think about control actions.»



Planners and regulators find this particularly appealing. Instead of just revealing that “renewables are associated with more congestion events”, causal explanations can quantify how much a specific reinforcement (a new line, a phase-shifting transformer, a storage asset) will reduce overload probability in different scenarios.

Bertram: And that closes the loop on our discussion about trust: if grid operators, planners, and regulators can recognize and challenge these “what-if” explanations, they can better judge when to rely on AI recommendations and when to override them – much like they already do with traditional planning studies and security assessments.

Whether we are raising children or developing AI systems, the roots of trust strengthen the wings of empowerment when coping with uncertainty and complexity. ■

Bertram Taetz (Prof. Dr. rer. nat.)

is Professor of Data Science and Artificial Intelligence at IU International University of Applied Sciences in Erfurt, Germany, where he has been teaching since 2022. He earned his PhD in Mathematics at Ruhr University Bochum in 2012 and has been with the German Research Center for Artificial Intelligence (DFKI) since 2013, where he leads a team on AI-based human motion capture, modeling, and analysis.

Rehana Mubarak-Aberer (Dr.) is a

Marketing Expert at OMICRON, where she has been working since 2007. Holding an MSc in Artificial Intelligence, an MA in International Technical Communication, and a PhD focusing on Machine Translation and Computational Linguistics, she is committed to interdisciplinary work that makes complex information intelligible across languages, domains, and human-machine systems.

WHEN OPERATIONAL TECHNOLOGY IS UNDER ATTACK

Why threat intelligence is essential
for protection technology

Hello Holger, cyberattacks targeting critical infrastructure, such as the recent attack on the Polish power grid in 2025, are on the rise. Why isn't the expertise of protection engineers enough to secure these installations anymore?

Holger Skurk: Our protection and control engineers understand their technology down to the smallest detail, but the rapid evolution of modern attack methods originating from IT is one of the challenges they're currently facing. This has resulted in a knowledge gap: while engineers know how to configure a protection device, identifying malware or complex attack patterns requires a specialist. Our OMICRON Threat Intelligence (OTI) service package closes this gap by putting IT security in the hands of the electrical power industry.

Why can't operators rely on established IT security solutions?

Because traditional IT tools don't speak the "language" of the electrical power industry. They don't understand what happens in an IEC 61850 bus or an IEC 104 connection. OTI, on the other hand, was developed specifically for OT. We offer Deep Packet Inspection for over 300 specialized protocols and 1,400 applications, providing a level of analysis that goes far beyond anything standard IT solutions can achieve.

What does OTI service improve in an engineer's daily work routine?

OTI is a comprehensive detection package that provides regularly updated Suricata signatures and so-called Indicators of Compromise (IoCs) that immediately stop known threats. Additionally, our behavioral detection engine detects atypical network behavior, known as anomalies, for specification. I am particularly proud of our vulnerability database, which is curated by experts: We collect security advisories and instructions from dozens of



OT manufacturers and automatically assign them to the devices in the network. This saves a significant amount of time when establishing asset security, as it only reports truly relevant vulnerabilities.

With many installations requiring isolation for security reasons, how can updates access these “air-gapped” areas?

That is a crucial OTI feature: unlike cloud-based IT solutions, it’s available offline. All updates can be installed in isolated OT zones without an Internet connection. Furthermore, our security analysts put each detection rule through rigorous quality assurance controls in advance to minimize false alarms.

What about the regulatory requirements? How does OTI help compliance with laws such as NIS2?

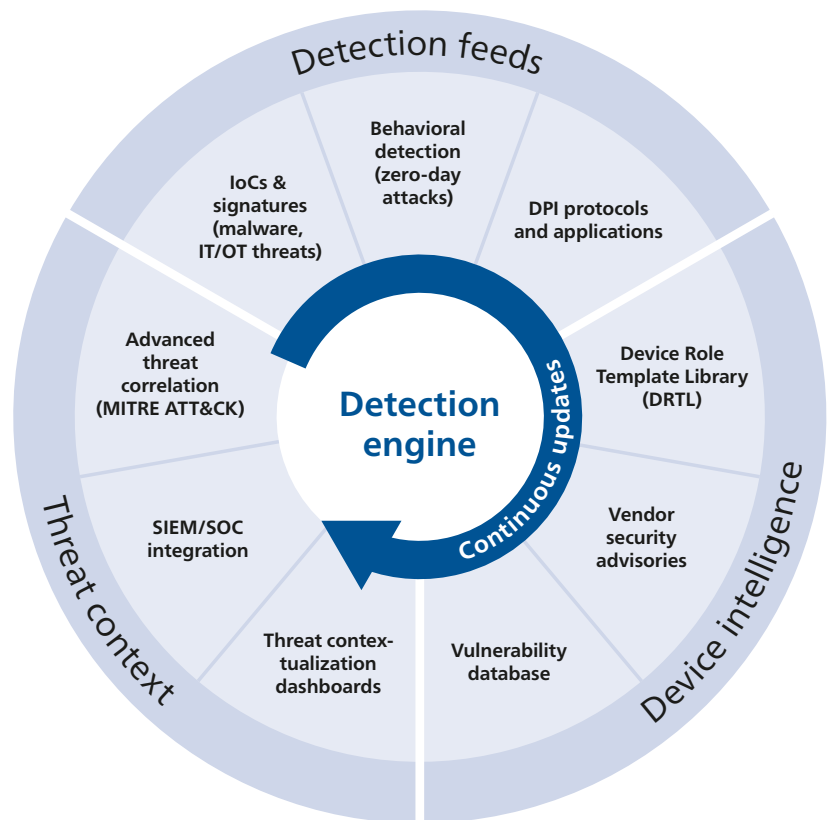
Compliance is a major topic today, which is why OTI ensures that alarms and contextual information are understandable to technicians without an IT security degree. We’re able to help operators meet NIS2, EnWG, and ISO 27019 requirements by integrating with SIEM systems and mapping to the MITRE ATT&CK® framework.

How can customers use this service?

OTI is an integral part of our StationGuard solution, provided via regular software updates and accessible in the OMICRON Customer Portal. This service has been developed by experts who understand both worlds, and it gives operators detection technology that protects their assets and keeps them technologically up to date. ■

Find out more about
OMICRON Threat Intelligence:

 omicronenergy.com/stationguard



Service overview of OMICRON Threat Intelligence (OTI)

*«I am particularly proud of our vulnerability database, which is curated by experts: **We collect security advisories and instructions from dozens of OT manufacturers and automatically assign them to the devices in the network.**»*



Holger Skurk,
Product Manager Cybersecurity,
OMICRON

KEEPING THE LIGHTS ON

Danny Chu, Principal Asset Engineer at ElectraNet Pty Limited – the South Australian transmission system operator and a global frontrunner for integrating renewable energy sources – joins us from Adelaide, South Australia, to discuss modern electrical testing.

As the backbone of South Australia's power grid, ElectraNet manages one of the highest wind-to-load ratios in the world. By developing massive infrastructure projects like the 900-kilometer Project EnergyConnect, they aren't just moving power – they're pioneering the cross-border transfer of renewable energy. This unique position makes ElectraNet a global leader that is solving the complex stability challenges of a 100% renewable future.

In this interview, Danny explains how OMICRON's new FRANEO 800 IT PQlyzer and its dedicated software help him and his team overcome complex challenges to maintain power quality and ensure total grid stability.

Hi Danny, it's nice to meet you and have the chance to discuss the relevance of this topic.

Can you tell us about your role at ElectraNet and how long you've been there?

Danny Chu: I've been with ElectraNet for 10 years across a variety of roles and projects, including asset management, operations, and maintenance. I'm currently a Principal Asset Engineer for Secondary Systems, managing short- and medium-term risks that maintain

the reliability of Southern Australia's power system. Every day can be a different challenge, but it's rewarding because our assets support keeping the lights on in South Australia.

Let's talk about asset testing at ElectraNet. What's the testing procedure like, and what's the overall strategy behind it?

We mainly use outsourced field testers for projects and maintenance, supported by an in-house team that investigates defects and refines test methods. This capability is vital as technology evolves rapidly.

Most investigations start with alarms that point to symptoms. If the root cause isn't clear on-site, we run further testing to narrow it down. Sometimes the



POWER QUALITY

Power Quality (PQ) measures how closely the grid's voltage and frequency match an ideal sine wave. As renewable inverters introduce high frequency "noise" and harmonics, maintaining PQ is vital to prevent asset overheating and system blackouts. To ensure grid stability, Instrument Transformers (ITs) must be validated for wideband accuracy, allowing operators to detect and mitigate these invisible distortions before they cause damage.

cause may even remain unclear after extensive checks. That's why adding more measurement points across the electrical network is important – it gives us the data we need to better understand contributing factors and strengthen future investigations.

Could you elaborate on your team's responsibilities and your role in day-to-day operations?

Secondary systems cover protection, control, automation, metering, monitoring, and auxiliary services. My daily routine involves Asset Engineering work and other disciplines that manage short-and medium-term risks. This includes reviewing defect and refurbishment scopes, refining routine maintenance, and investigating

defects – often resulting in updates to design standards or maintenance practices.

To give us a clearer picture: How many assets does ElectraNet manage, particularly when it comes to instrument transformers?

ElectraNet manages over 4,000 instrument transformers across the South Australian transmission network. These include a diverse mix of technologies such as capacitive voltage transformers (CVTs), inductive voltage transformers (IVTs), current transformers (CTs), and combined current and voltage transformers. Each plays a critical role in enabling accurate measurement, protection, and monitoring to ensure the safe and reliable operation of the grid.

Can you tell our readers about the role instrument transformers play in the power quality measurement chain?

Instrument transformers are fundamental for power quality, enabling accurate and safe voltage measurement. They help us meet our obligation under the National Electricity Rules, including monitoring up to the 50th harmonic.

Many of our assets are CVTs: While they're excellent for power-frequency operation, their suppression-unit design creates frequency-dependent ratio errors. This means their secondary output isn't inherently suitable for wideband PQ measurements without compensation. ▶



This factor highlights the importance of using instrument transformers that deliver a reliable wide-band performance, especially as power quality monitoring becomes increasingly critical in modern, dynamic transmission networks.

You recently started auditioning new transformer technology – the RC divider. What drove your decision, and what are the advantages of using a non-conventional instrument transformer?

We auditioned low-power instrument transformers (LPITs), specifically the CR and RC divider technologies, to test their wideband and transient performance in the field. This was driven by the rise of inverter-based resources such as solar, wind, and battery storage systems in the network. These technologies interact with the grid, requiring more advanced and accurate measurement solutions.

Our initial studies showed that LPITs provide superior frequency

response and stable accuracy across a range of temperatures. These insights enable more effective monitoring and diagnostics, ensuring better grid performance and long-term stability.

Why are wideband-accuracy instrument transformer measurements critical for power quality applications? Is this, e.g., driven by Market Operator requirements, or is it an ElectraNet initiative?

Accurate wideband and transient measurements are vital for monitoring power quality at key transmission points. As more inverter based resources connect to the grid, capturing high frequency effects like harmonics, oscillations, and transient switching becomes critical. This enables ElectraNet to meet its obligations to the Transmission Network Service Provider under the National Electricity Rules. Furthermore, it reflects our proactive commitment to reliability and a secure energy future for South Australia.

How has ElectraNet's approach to power quality and instrument transformer testing evolved? What role does the current strategy play in ensuring grid stability and operational efficiency?

We started with a small number of power-quality meters in key strategic locations, supported by portable units. However, the network's dynamic nature made it difficult to ensure long-term, consistent data.

We implemented a comprehensive power quality monitoring program during several regulatory tests, using permanent measurement nodes and sensors throughout the transmission network. We're currently focused on robust site integration and post-modification validation aligned with manufacturer recommendations. This strategy supports grid stability and efficiency by providing the high-resolution data required for proactive power-quality and system-performance management.



How did you first learn about OMICRON's FRANEO 800 IT PQlyzer?

I first learned about it at an OMICRON technical event, where I discussed the challenge we faced because we lacked practical field validation tools for measuring instrument transformer frequency response. At the time, we were preparing to install a Low Power Instrument Transformer (LPIT) and needed a simple, repeatable solution. OMICRON connected us with their experts, and they explored LPIT use cases with us by testing methodologies and design considerations. When the prototype was ready, we tested it on several IVTs and gained valuable insights from our hands-on experience.

Were you skeptical at first, considering this was an entirely new approach?

Like any new technology, I had initial reservations about adopting the test set – mainly its around suitability for ElectraNet's power quality

*«Many of our assets, especially CVTs, were never designed for modern wideband PQ measurements. **With increasing inverter-based resources, that gap became critical.»***

Danny Chu,
Principal Asset Engineer,
ElectraNet Pty Limited

applications, test-result repeatability, and robustness in the field.

Many of these concerns were addressed during the prototype testing phase, where we gained hands-on experience with the equipment. The test set demonstrated consistent, repeatable

results across multiple users, provided that factors such as polarity and stray capacitance from coaxial cables were accounted for. The software's flexibility, which allows users to reduce test times by adjusting the sampling rate, was another strong point. The battery-powered option, which makes ▶



the system independent of a local power source and enhances field usability, was another key benefit. We're currently in the final phase of our evaluation at OEM factory labs, where we continue to validate its performance and reliability.

ElectraNet is at the forefront of integrating renewable energy into the grid. What kinds of challenges and technical issues did you encounter during the integration process?

Exciting opportunities and complex technical challenges are both part of expanding renewable integration. We are currently addressing key issues such as:

1. Increased switching activities due to dynamic generation and load behavior.
2. More dynamic power flows require flexible and real-time control.

3. Reduced system inertia as synchronous machines are replaced by inverter-based resources (IBRs).
4. More disturbances, such as oscillations and high-frequency harmonics, require advanced monitoring and power-quality migration.

Does OMICRON help you manage or mitigate these challenges?

Yes, our collaboration with OMICRON has given us a better understanding of several of these challenges, and they've influenced our investigative efforts. Sharing insights about network issues and field integration has improved our assessments of instrument transformer measurement capabilities and supports the integration of advanced power-quality monitoring across the transmission network.

The trial and implementation of the FRANEO 800 IT PQlyzer was a key

outcome of our partnership with OMICRON. It allows us to assess transformer performance and suitability both after site integration and in brownfield retrofit scenarios. The well-characterised frequency response it provides lets us interpret PQ data with greater technical precision and confidence.

Buzzwords like renewable energy, grid stability, and vulnerability are being used a lot these days. Where do you think the future of electrical testing is heading in this evolving energy landscape?

As electrical networks become increasingly complex, the nature of testing and assessments is evolving accordingly. I believe the future of electrical testing lies in integrating advanced modelling and simulation techniques to study network abnormalities observed in the field.



We're moving beyond traditional field testing to validating components in detailed digital models using platforms like real time digital simulators (RTDS). This lets us study system performance safely and efficiently before field validation. These tools will be essential to grid stability and resilience as we continue to integrate more renewable energy sources into the network.

Danny, thank you so much for this insightful conversation. We appreciate your time and having the opportunity to learn more about your work at ElectraNet!

Thank you for the opportunity – it's been a pleasure collaborating with the OMICRON team. I truly value our partnership and look forward to exploring more innovative and robust testing solutions from OMICRON in the future. ■

«With the transformer frequency response now well characterised, we can interpret power quality data with far greater technical precision and confidence.»

ELECTRANET

- › **Headquarters:** Adelaide, South Australia.
- › **Infrastructure:** Over 6,900 km (4,290 mi) of high-voltage transmission lines and 100 substations.
- › **Asset value:** More than \$4.5 billion AUD.
- › **Renewable leadership:** Australia's largest wind generation connector; one of the highest global wind-to-load ratios.
- › **Flagship project:** Project EnergyConnect – a 900 km (560 mi) interconnector linking South Australia, New South Wales, and Victoria.

WHEN SAFETY AND TIMING ARE NO LONGER A TRADE-OFF

How both-sides grounding and DRM enable reliable HV CB testing.

Timing tests are a key element for assessing the condition and reliability of high-voltage circuit breakers. They provide valuable insight into mechanical wear, contact condition, and switching behavior, and are an integral part of factory acceptance testing, commissioning, and routine maintenance in substations. As safety requirements in the field continue to increase, expectations for the applied test methods are rising as well.

The challenge: safe grounding with precise timing measurements

Typically, conventional voltage-based timing methods only allow one side of a circuit breaker to be grounded. In live

substations, this can lead to hazardous potentials on ungrounded metallic parts, posing a greater safety risk to test engineers. Grounding the circuit breaker on both sides significantly improves safety. However, it also affects resistance-based measurements, as the ground resistance acts in parallel with the circuit breaker. As a result, switching states may no longer be clearly distinguishable, potentially reducing measurement accuracy.

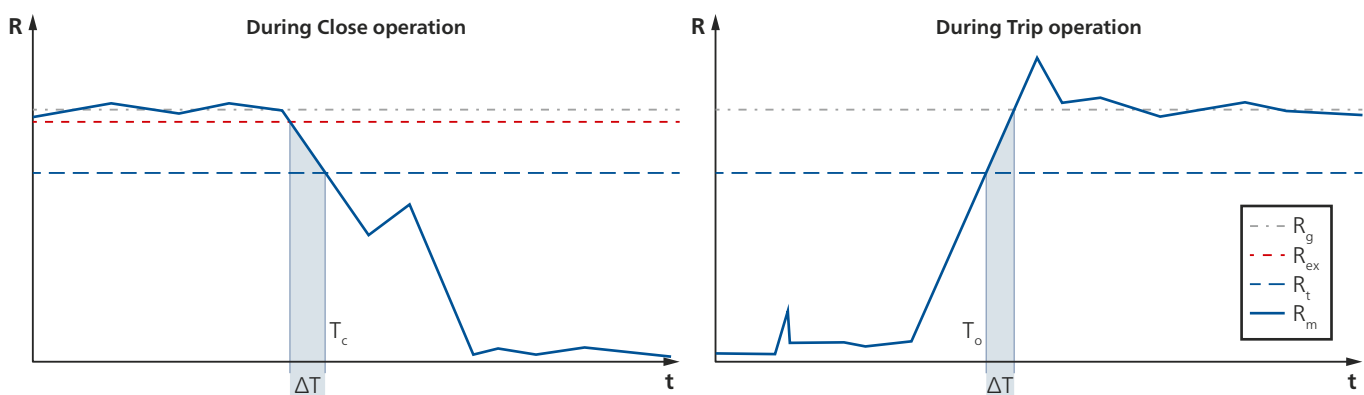
The approach: DRM with both-sides grounding

Dynamic Resistance Measurement provides a practical approach for performing timing tests safely on both-sides

grounded circuit breakers. By carefully defining threshold values and systematically evaluating the influence of ground resistance, the switching state can be determined reliably. Additional evaluation methods help minimize the impact of disturbances, such as measurement noise and mechanical vibrations, enabling realistic assessments of timing accuracy. This makes DRM a powerful method for safe and reliable timing measurements in the field.

Proven in practice on different circuit breakers

When ground resistance exceeds a certain level, modern SF₆ high-voltage circuit breaker measurements dem-



Qualitative representation of determination of inaccuracy.

onstrate that DRM with both-sides grounding delivers stable and reproducible results. The observed deviations remain well within the applicable normative tolerances for closing and opening operations.

Tests performed on older oil circuit breakers show the significant role contact condition plays in measurement accuracy. Worn or damaged contacts can delay or obscure first-contact detection, particularly during closing operations, leading to increased timing deviations. Nevertheless, DRM remains suitable for both-sides grounded

timing tests on circuit breakers with intact contacts and sufficiently high ground resistance.

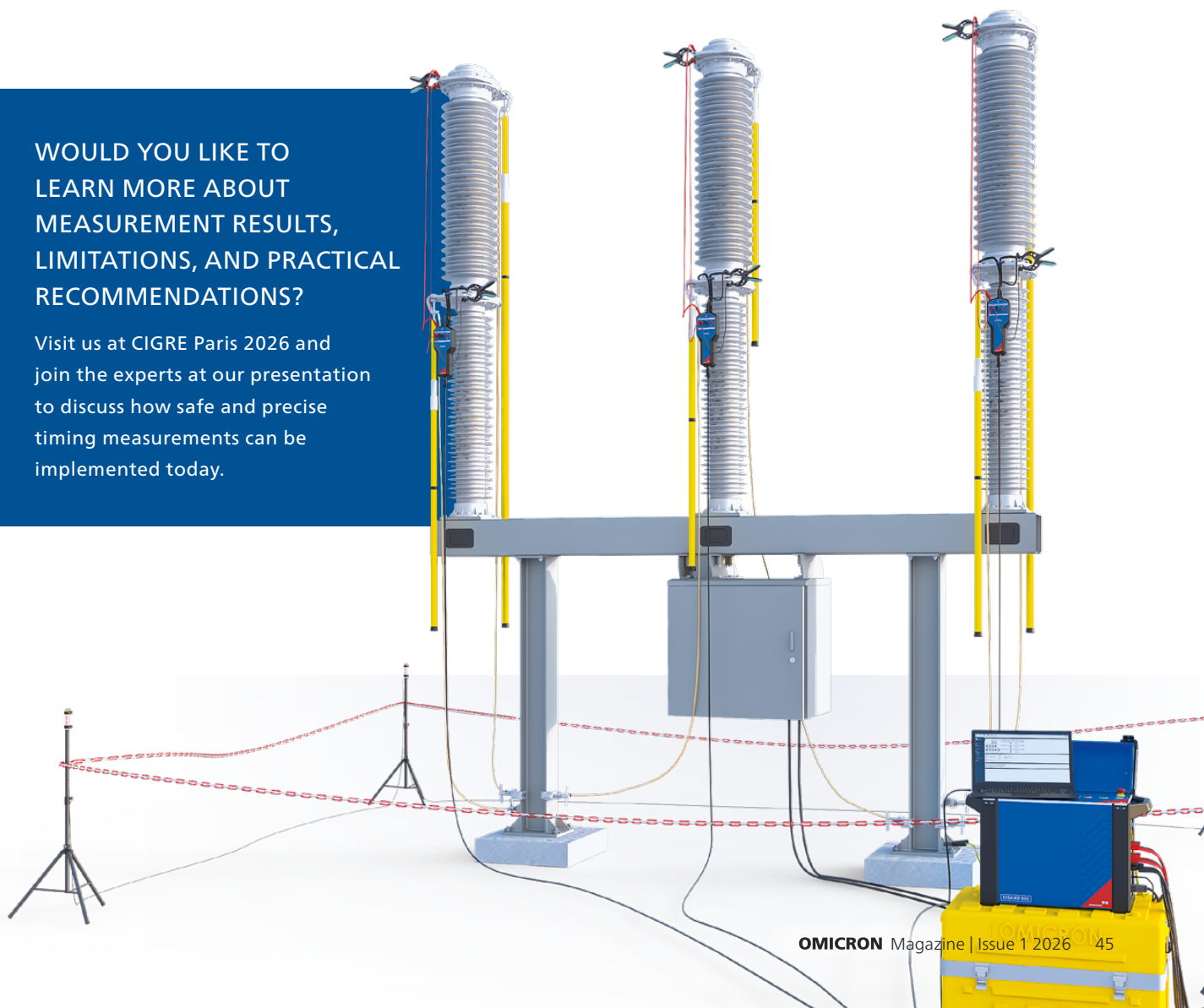
DRM also provides a clear distinction between the open and closed states of circuit breakers with multiple interrupting chambers. Individual interrupting chambers can be evaluated separately by using independent current sources. At the same time, the system remains safely grounded during the installation and removal of the test equipment, significantly improving safety for test engineers.

Timing under control

The DRM and both-sides grounding combination successfully balances enhanced safety with practical measurement accuracy, representing a valuable extension to established timing test methods. It enables reliable testing under real field conditions when applied under well-defined conditions. Implementing it with our solutions, such as specialist CIBANO 500, DRM supports efficient, safe, and consistent circuit breaker testing throughout an entire asset lifecycle. ■

WOULD YOU LIKE TO
LEARN MORE ABOUT
MEASUREMENT RESULTS,
LIMITATIONS, AND PRACTICAL
RECOMMENDATIONS?

Visit us at CIGRE Paris 2026 and
join the experts at our presentation
to discuss how safe and precise
timing measurements can be
implemented today.



ISIO 200 IN PRACTICE: CUSTOMER VOICES

ISIO 200

Binary input/output (I/O) terminal
with IEC 61850 interface

- › Testing for complex protection schemes with CMC test sets
- › Remote control for binary outputs
- › Indications for GOOSE timeouts and malfunctions using alarm output contact
- › Integrates conventional devices into IEC 61850 systems
- › Status interface with data models for overcurrent relays, switchgear, and teleprotection



FROM MANUAL EFFORT TO A SMART SOLUTION: ISIO 200 AT AMPRION

The demands placed on network operators are constantly increasing – complex protection systems must be reliably tested and approved without exceeding time and cost constraints. Amprion, one of Germany's leading transmission system operators, relies on innovative solutions to meet these challenges. In our conversation with Jochen Heimann, a secondary technology technician, we learned how the ISIO 200, a CMC accessory, has revolutionized test sequence automation. Additionally, Jochen discussed the practical advantages of using the CMC accessory with us and shared his wishes for the future. With many years of hands-on experience, Jochen operates and tests protection and control systems. He has been working in the operating departments at VEW, RWE and Amprion since 1994. He started out as a technician for protection and station control technology and later became an engineer. Since the beginning of 2015, he has been working at Amprion's standards department for secondary technology, where he shares joint responsibility for test strategies and concepts.

What motivated Amprion to use the CMC accessory?

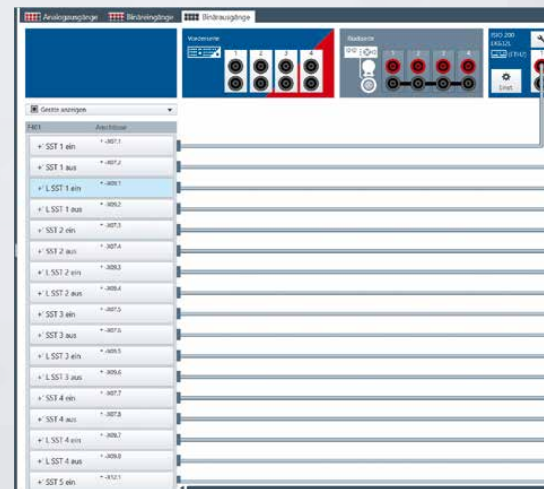
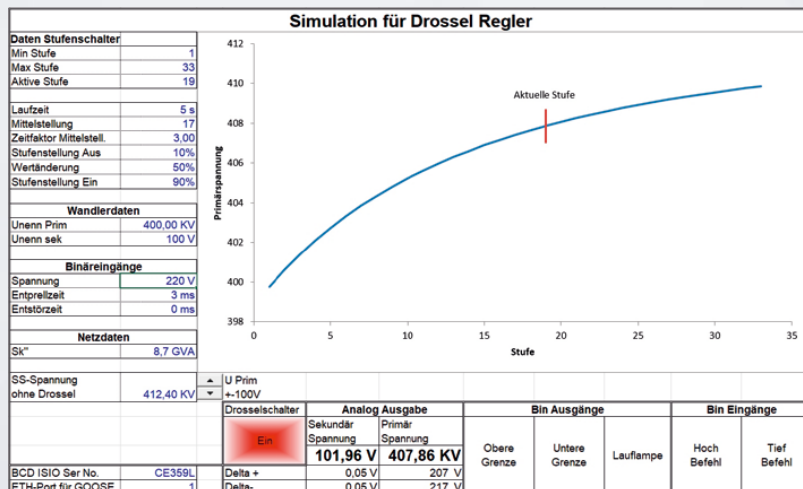
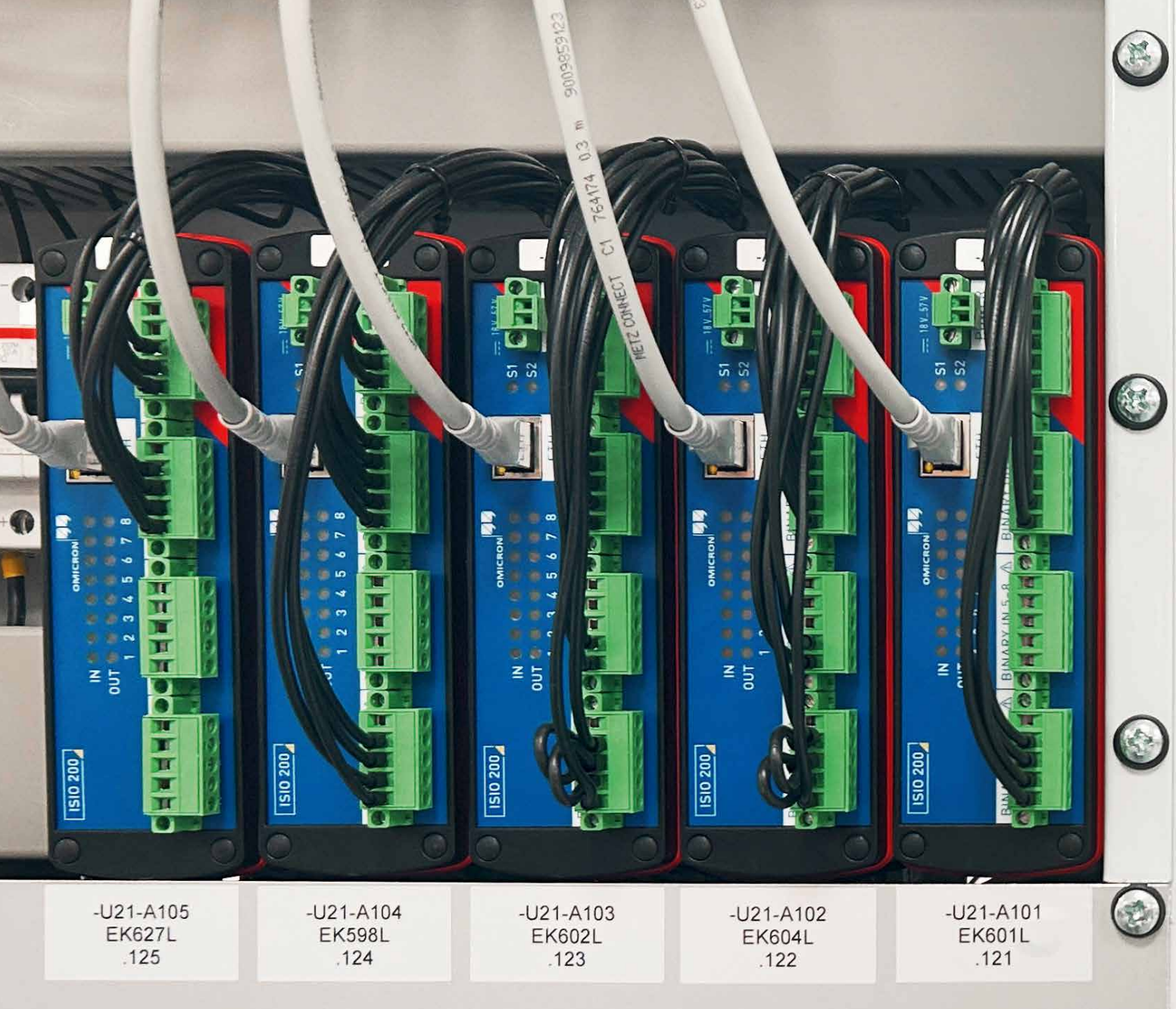
Jochen: About seven to eight years ago, we carried out factory acceptance testing (FAT) on an MSCDN (Mechanically Switched Capacitor with Damping Network) protection cabinet. After extensive laboratory preparation, we wanted to perform the acceptance test as quickly as possible. We needed additional inputs and outputs to switch the numerous protection functions, and we used the CMC accessory for the first time to automate this process. ▶

«Conducting FAT for a busbar protection system used to take up to five days, but now they are usually completed in two days, and that is what I call real progress.»



Jochen Heimann,
Secondary Technology Technician,
Amprion GmbH





Excel simulator for shunt reactors

Are there other applications for it?

Yes, we use it regularly. We often require more than four binary outputs, and that is exactly when this tool becomes very handy. Some examples include acceptance for a controllable 250 MVA reactor with circuit breaker simulation, step feedback (BCD code), and SCADA simulation using an Excel tool with CMEngine. We have also upgraded our busbar protection test system with it to simulate switching device feedback. We also used it for another project that required us to set up a large test site for three-terminal protection that could simulate all possible states.

Have you noticed any benefits or improvements?

One major benefit is its increased automation capabilities. We used to manually output switching device feedback for our busbar protection systems. Today, control is automatic, with a fixed test sequence, which significantly increases reproducibility and testing speed. Conducting FAT for a busbar protection system used to take up to five days, but now they are usually completed in two days, and that is what I call real progress.

Did using ISIO 200 devices present you with any challenges?

At first, using the multiple settings in the web interface was a bit challenging. Even now, new colleagues do not find it to be self-explanatory. However, once they have used it, the logic behind it becomes clear.

Would you recommend the accessory to other network operators or specialists? Why?

Absolutely! If you need a vast number of outputs, the ISIO 200 comes highly recommended. It really makes multiple testing tasks easier.

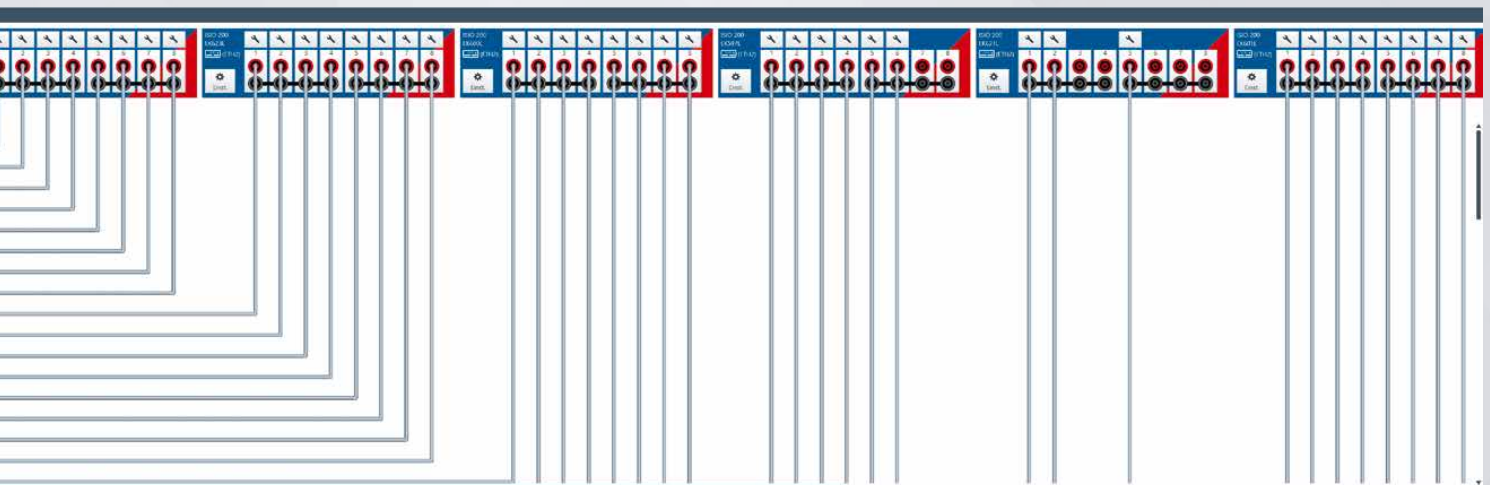
Do you have any suggestions or requests?

Yes – we would like to see more than eight inputs and outputs, as we are using multiple ISIO 200 devices in our busbar protection systems. So, we would find being able to scale that up very helpful. Many of our outputs are already occupied, and only a few inputs are still available. Busbar protection depends on receiving information from the system, and although we are controlling the entire system with RelaySimTest, little information comes back to the test system. The ratio is about 3:1.

For example, I would like to order the device with 12 outputs and 4 inputs. Potential-free outputs would also be beneficial, since four of our outputs are always interconnected. So, that would give us more connection options.

Lastly, it would also be an advantage if there were an option to purchase the ISIO 200 with push-in connection terminals (instead of just screw terminals).

Thank you very much for the interview, Jochen. ▶



Test set configuration in RelaySimTest with ISIO 200 devices for busbar protection

PROTECTION TESTING FROM FAT TO SAT: ISIO 200 AT ELIA

Elia, Belgium's transmission system operator responsible for the reliable transmission of electricity between producers and distribution system operators, plays a leading role in the energy transition by integrating renewables, ensuring grid stability, and driving innovation towards a sustainable power system. Within Elia, the OCE SecSys National Protection department ensures the reliability of high-voltage grid protection systems, where FAT at manufacturer sites is a key step that guarantees quality and performance. Mats Van Belle has been with Elia since 2018, and we spoke to him to find out how Elia is applying ISIO 200.

How has your role at Elia evolved since 2018? When did you start using ISIO 200 devices?

Mats: For the first six years, I worked in the secondary systems department as a regional maintenance and commissioning technician. That is where I became familiar with various OMICRON test sets, focusing mainly on the CMC 256plus. In 2024, I switched to the central secondary systems department, specializing in protection systems. I discovered and utilized advanced functionalities of different CMC devices, and also used the ISIO 200 modules to extend the CMCs.

What prompted you to start using the ISIO 200 as a CMC accessory?

It was added to our testing setup when our latest framework agreement,

"SPACS 3", began in 2021. From that point onwards, we began combining multiple protection functions. We combined individual protection tasks or algorithms, such as overcurrent protection, distance protection, differential protection, and earth fault protection, into a single IED, whereas previously, we used a separate IED for each protection function.

This consolidation naturally increased the number of signals each device had to manage. In SPACS 3, we divided the cubicle into three zones: two protection zones and one control zone. Switching from one zone to another still requires reworking most of the wiring from the CMC test set (including analog signals): for example, we use different current transformer (CT) cores for the different zones, and in the control zone the busbar voltages are also necessary, so the analog connections change as well.

A few general signals, like trips and start back-up, have not changed. To improve efficiency and reduce the time required for a FAT, we looked for a solution that allowed us to test each zone without changing the connection. The ISIO 200 modules were the logical choice, as they allow for the integration of all outgoing signals into automated tests and centralized monitoring/validation of all incoming signals via the same OMICRON Control Center (OCC).

Has using the ISIO 200 modules offered you any other benefits?

Adding them has proven very effective in reducing the time required to complete FAT, enabling us to deliver a comprehensive OCC file to regional departments for their use during Site Acceptance Testing (SAT). By reusing the OCC file created during FAT, we help reduce their workload and provide clear explanations of the protection logic and testing procedures.

What does your test setup look like?

Since using ISIO 200 accessories often involves frequent rewiring or relocation, we decided to house the modules in a portable box. This box contains two ISIO 200 modules, a switch, with all input/output signals routed to the front via banana sockets for quick, easy wiring. This design not only facilitates flexibility, but it also protects the accessories during transport and minimizes wear on the screw connectors.

Would you recommend the accessory to other users?

I highly recommend adding ISIO 200 terminals to any test setup when available inputs and outputs are insufficient, or when additional outputs can minimize manual interaction, given the CMC's limitations as a standalone device. Having all outputs from the IED available in one test session makes it easy to automatically validate all required positive and negative tests. Not only will it verify that protection functions are operating

correctly after all enabling conditions have been fulfilled, but it also ensures they remain inoperative when required conditions are missing.

For example, when testing distance protection, we verify that the function is not triggered when an enabling condition is missing. Likewise, during tests of a certain zone where teleprotection sending or start back-up should not be activated, we explicitly check these signals using a state assessment (expected value = 0).

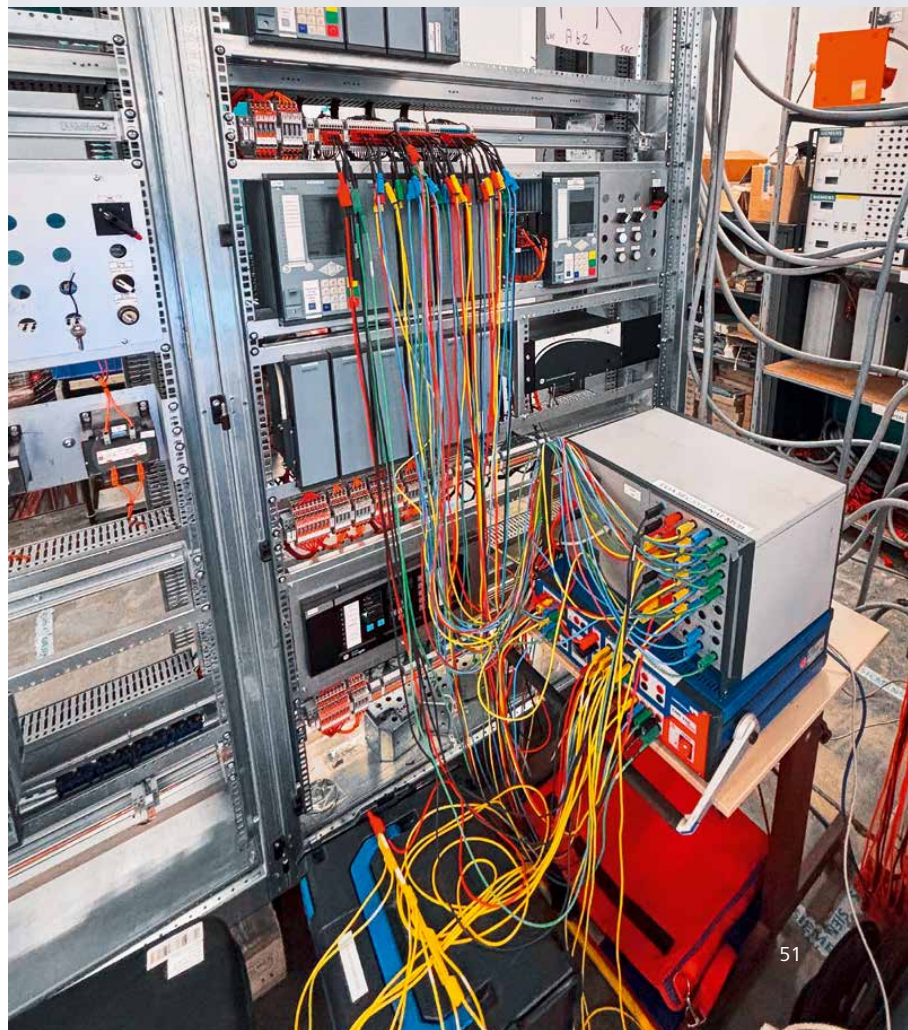
Repeating tests or compromising which signals need to be monitored becomes unnecessary. Should questions arise later, you always have a complete overview of all signals. Furthermore, automation of testing – including the simulation of necessary external signals – is much easier, dramatically reducing (or eliminating) manual steps.

Thank you for your valuable insights, Mats. ■

«Having all outputs from the IED available in one test session makes it easy to automatically validate all required positive and negative tests.»



Mats Van Belle,
Technician, Protection Systems,
Elia Asset



WHAT'S GOING ON

We are continuing to share our knowledge. We are going to reach out to you physically or digitally with our events, trade shows, conferences, webinars and training courses. Keep yourself up to date by checking out our events and training courses.

Scan QR-Code to get fast access to all links:



OMICRON ACADEMY COURSES & WEBINARS

omicronenergy.com/training
omicronenergy.com/recordings



OMICRON EVENTS

omicronenergy.com/events



OMICRON ENERGY TALKS

omicronenergy.com/podcast

WE ARE LOOKING FORWARD TO SEEING YOU.