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POWER SYSTEMS TECHNOLOGY

PST POWER SYSTEMS TECHNOLOGY

POWER SYSTEM DYNAMICS: A RAPIDLY CHANGING LANDSCAPE

MONITORING THE MOST CRITICAL COMPONENTS ON POWER TRANSFORMERS

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TRANSFORMER TECHNOLOGY MAG

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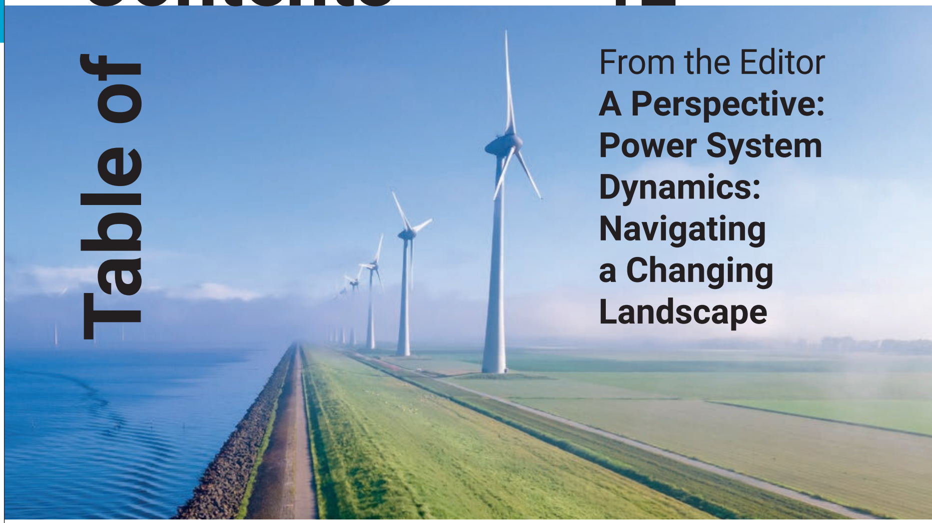

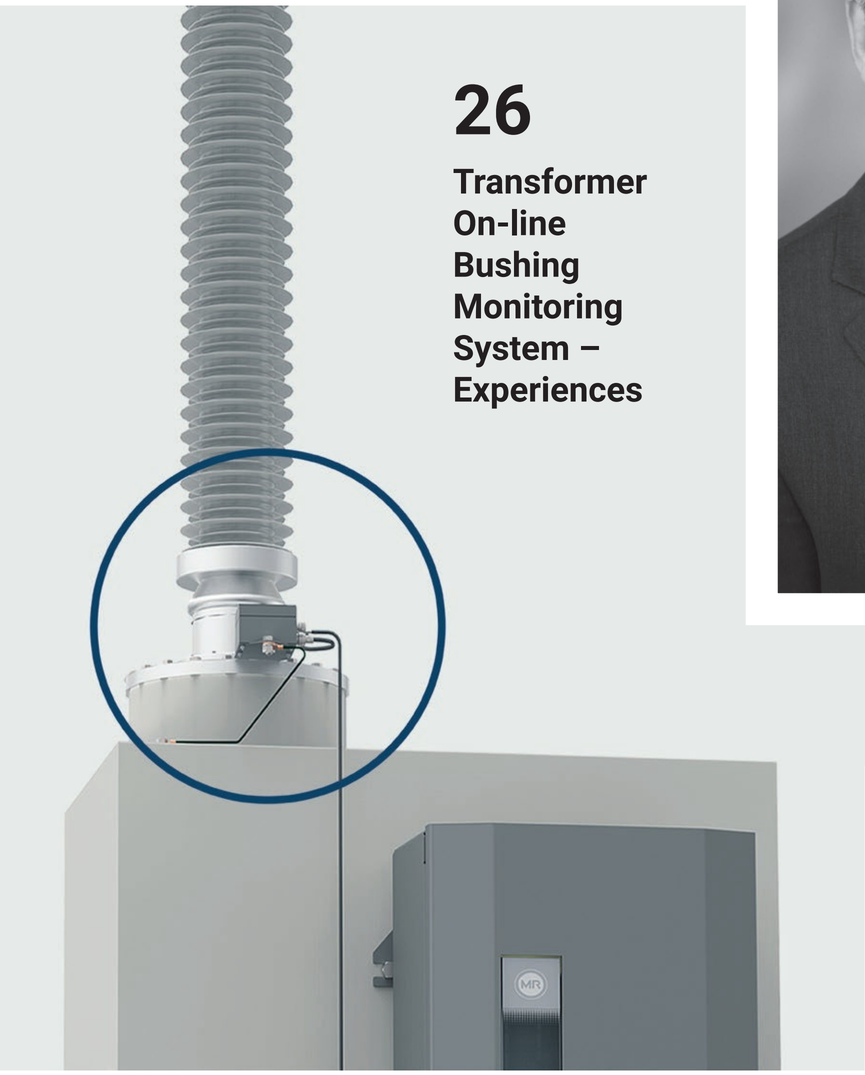

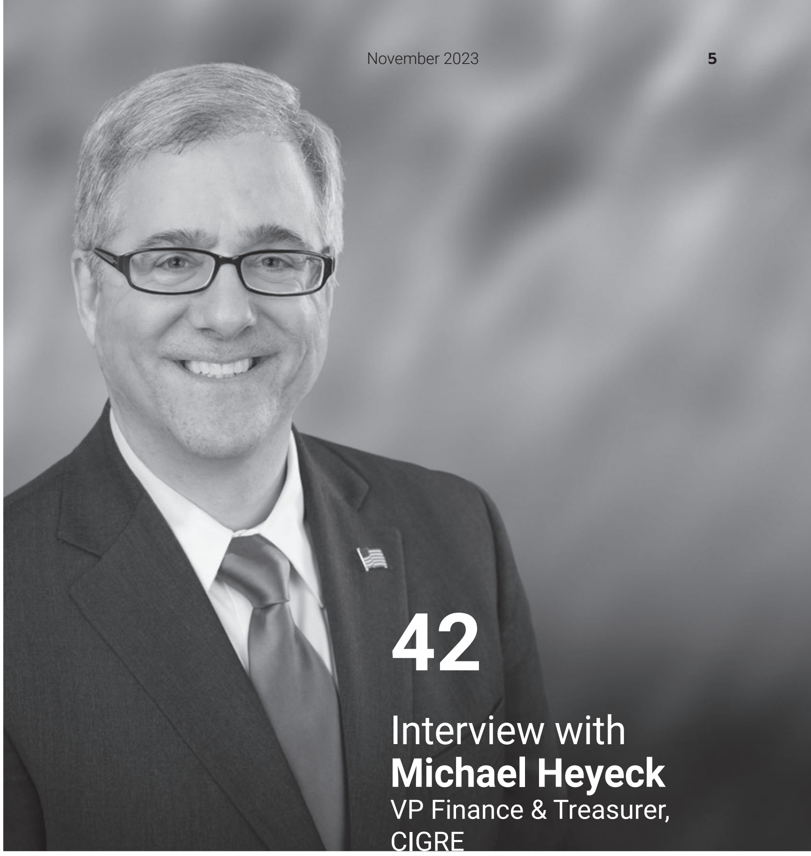

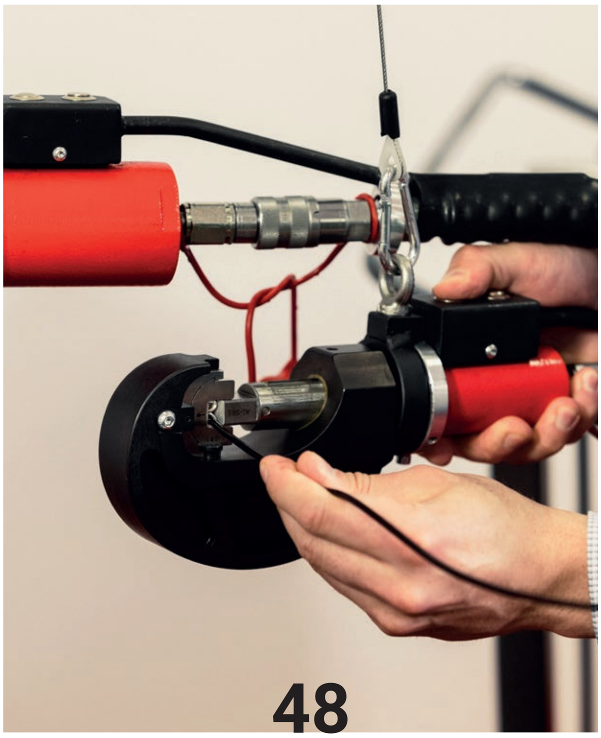

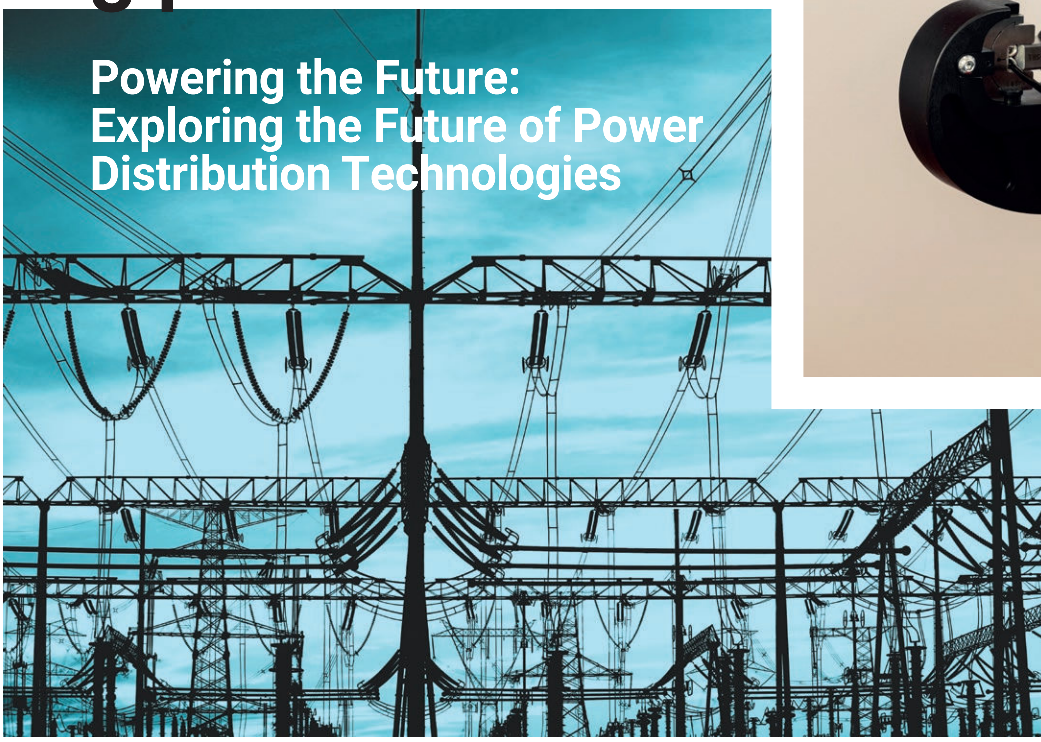

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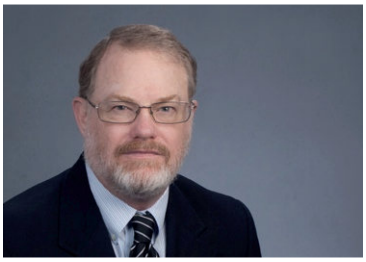

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Power System Dynamics: Navigating a Changing Landscape

Over the years, advancements in technology and the increasing demand for renewable energy sources have led to significant changes in the power grid. As we have expanded our magazine coverage from Transformer Technology to Power Systems Technology, you will see that our focus is on the entire power grid from generation to the adoption of EVs. We will also maintain our focus on transformers, as in our December issue themed ***Insulation Systems, and Oils & Fluids***, one of our most downloaded and important issues we publish every December. This issue, ***Power System Dynamics: A Rapidly Changing Landscape***, embodies the current state of power grids globally. The only constant in power grids is that we are in the midst of the most important changes in how electricity is generated, transmitted and distributed in decades.

The only constant in power grids is that we are in the midst of the most important changes in how electricity is generated, transmitted, and distributed in decades.

One of the most notable changes in the power grid is the integration of renewable energy sources. Traditional power grids heavily rely on fossil fuels, such as coal and natural gas, for electricity generation. However, with the growing concerns about climate change and the need for sustainable energy, renewable sources like solar and wind power have gained popularity.
The integration of renewable energy sources into the power grid has brought about several challenges and opportunities. Unlike traditional power plants, renewable energy sources are intermittent, creating challenges when the sun is not shining or the wind blowing. This variability poses challenges for grid operators in maintaining a stable supply of electricity. To address this, advanced technologies like energy storage systems and smart grids are being implemented.

Energy storage systems play a crucial role in balancing the intermittent nature of renewable energy sources. They store excess energy during periods of high generation and release it during times of low generation, ensuring a consistent power supply. At the most recent RE+ event in Las Vegas, with over 40,000 attendees, it was clear that storage, wind, and solar are interdependent technologies during this time of change. We will focus on these changes in our January/February issue, ***Green Energy Technology: Solar, Wind and Storage***.

Additionally, smart grids enable real-time monitoring and control of electricity flow, allowing grid operators to optimize the use of renewable energy and improve overall grid efficiency. This year we attended the IEEE PES Grid Edge Conference and Expo in San Diego which focused on the changes taking place as grid modernization becomes the industry's focus. The modern grid is adapting to weather events, variability in generation and the changes at the grid edge where the change from rate payers to customers, with "prosumers" becoming more prominent than consumers.

Photo: Shutterstock

As we continue to transition towards a more sustainable and resilient power grid, it is crucial to adapt and embrace these changes for a greener future.

Another significant change in the power grid is the increasing decentralization of power generation. Traditionally, power plants were large, centralized facilities located far away from consumers. However, with the rise of distributed energy resources like rooftop solar panels and small wind turbines, power generation is becoming more localized.

Decentralization offers several benefits, including reduced transmission losses and increased resilience. By generating electricity closer to the point of consumption, energy losses during transmission are minimized. Moreover, in the event of a power outage or natural disaster, localized power generation can provide backup electricity, enhancing the grid's resilience.

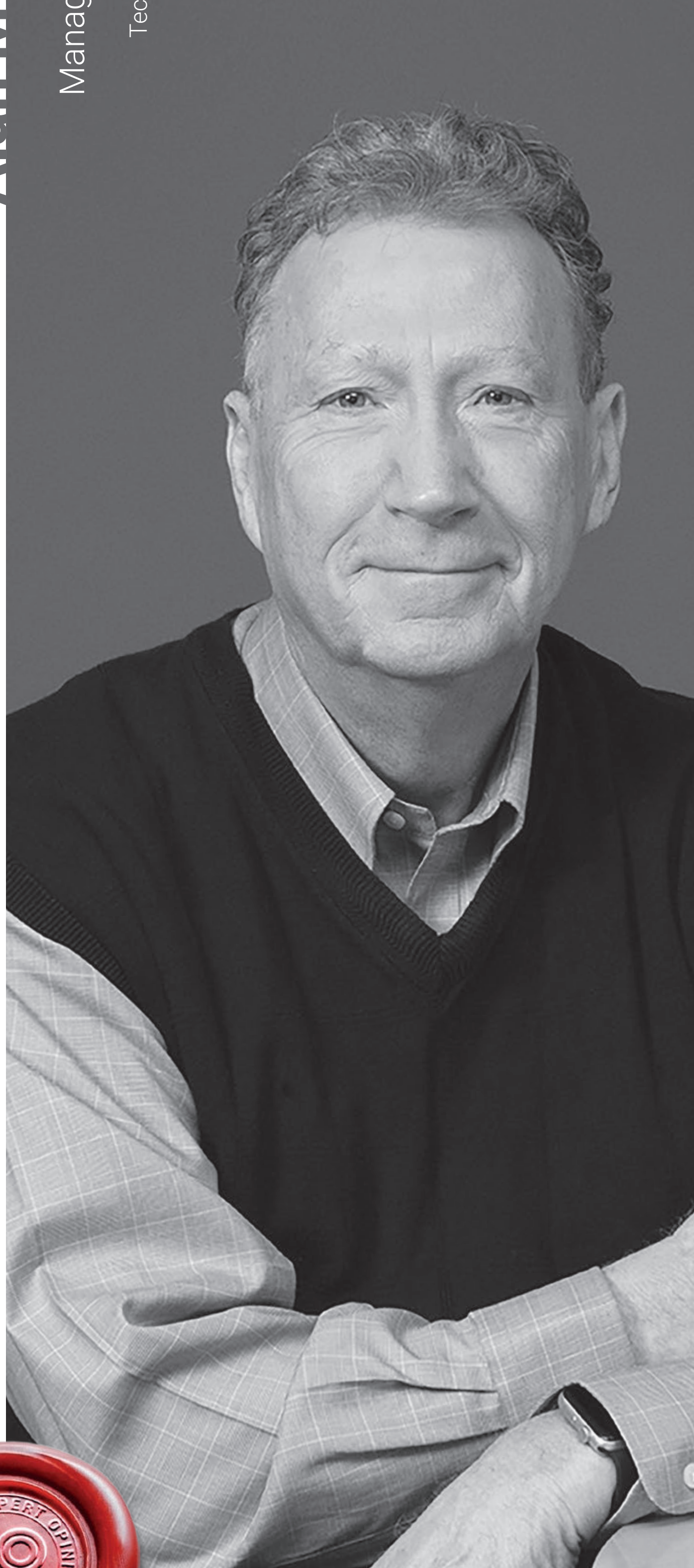
Furthermore, the changing power grid is also witnessing the adoption of electric vehicles (EVs). As more people switch to EVs, the demand for charging infrastructure is increasing. This necessitates upgrades to the power grid to accommodate the additional load. Smart charging stations and vehicle-to-grid (V2G) technology are being developed to manage the charging and discharging of EVs efficiently.

In conclusion, the power grid is undergoing significant changes driven by the integration of renewable energy sources, decentralization of power generation, and the rise of electric vehicles. These changes bring both challenges and opportunities, requiring the implementation of advanced technologies and infrastructure upgrades. As we continue to transition towards a more sustainable and resilient power grid, it is crucial to adapt and embrace these changes for a greener future.

It is our goal at APC Media to provide up to date, practical, and significant articles, interviews, and perspectives. We hope you find this current issue, one that achieves that goal. Enjoy!

Alan M Ross
CRL, CMRP
Managing Editor
APC Media
Technical Director

Alan has decades of experience in the power systems industry and is one of the greatest reliability experts out there.



ODSR - a Simple Solution to a Complex Problem

Photo: Shutterstock

In the intricate realm of asset management, organizations often find themselves entwined in the complexities of maintaining optimal safety, reliability, and efficiency. Operations Driven Safety and Reliability (ODSR) emerges as a breath of fresh air, showcasing that solutions to complex problems don't necessarily have to be complicated. The KISS principle – "Keep It Simple, Stupid" – stands relevant in this context, advocating for simplicity as the route to efficiency and effectiveness.

OPERATIONS DRIVEN SAFETY AND RELIABILITY (ODSR) EMERGES AS A BREATH OF FRESH AIR, SHOWCASING THAT SOLUTIONS TO COMPLEX PROBLEMS DON'T NECESSARILY HAVE TO BE COMPLICATED.

Martin Robinson is the founder, owner, and CEO of IRISS Inc., a leading manufacturer of infrared inspection windows. Robinson focuses on innovation and is a pioneer of Electrical Maintenance Safety Devices (EMSDs) that help protect technicians from harm while protecting their companies' bottom line. He holds several patents for condition-based maintenance devices and has designed multiple maintenance programs that include infrared, ultrasound, partial discharge testing, non-destructive testing (NDT) and energy management strategies. He holds a NEBOSH certificate in Occupational Safety and Health, an IAM Certificate in Asset Management, is a certified Level III Thermographer, a Certified Maintenance and Reliability Professional (CMRP) and a Certified Reliability Leader (CRL). He is a member of IEEE, NFPA and is a standing member on the technical committee CSA Z463 guidelines on maintenance of electrical systems.

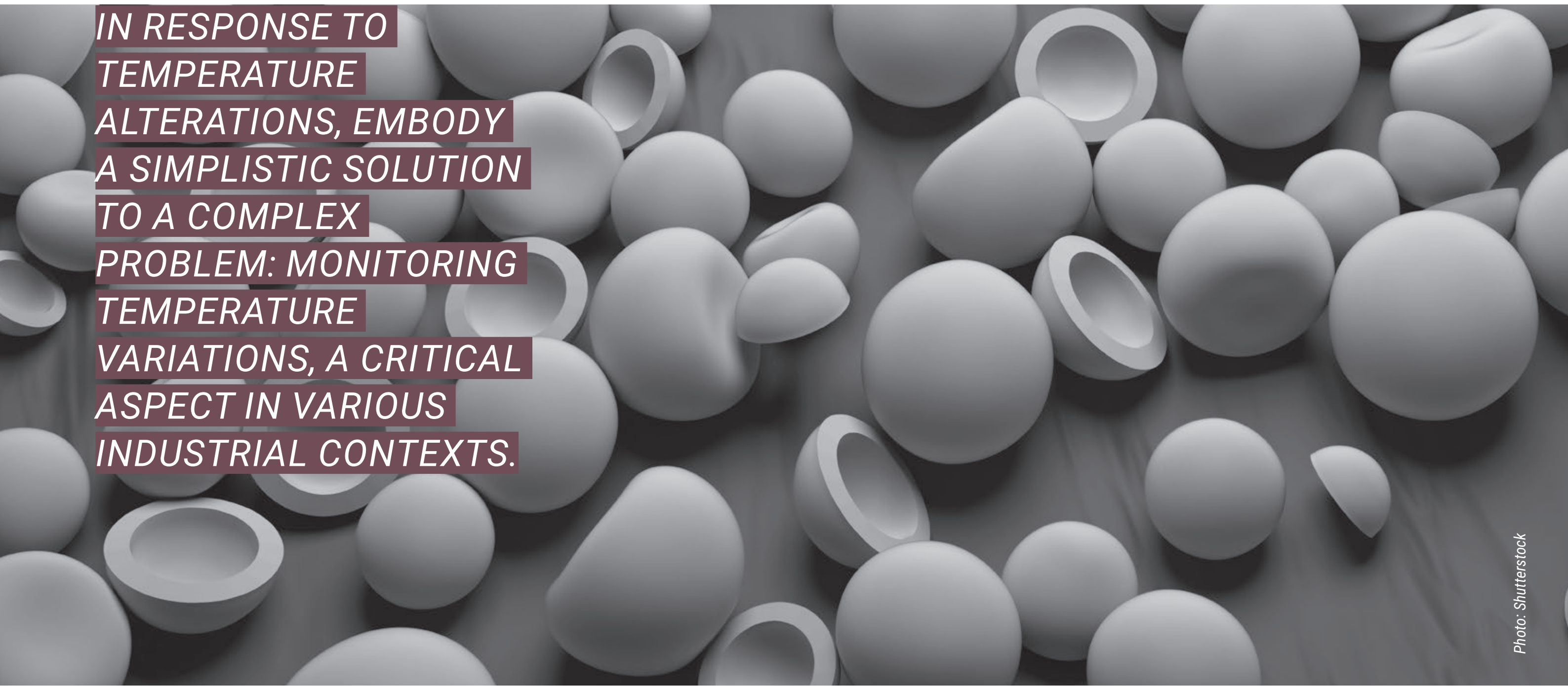
Written by **Martin Robinson**

The Essence of ODSR and The Kiss Principle

ODSR revolves around employing operational insights to enhance the safety and reliability of organizational assets. By valuing operator feedback, analyzing performance data, and strategically employing this information to inform asset management and design, ODSR simplifies the intricate choreography of safeguarding assets and operations. The KISS principle and ODSR intertwine harmoniously, offering a structured yet uncomplicated approach to enhancing operational safety and reliability.

Using thermochromic materials is a pertinent example of marrying simplicity with sophistication in asset management. Thermochromics, materials that change color in response to temperature alterations, embody a simplistic solution to a complex problem: monitoring temperature variations, a critical aspect in various industrial contexts.

THERMOCHROMICS, MATERIALS THAT CHANGE COLOR IN RESPONSE TO TEMPERATURE ALTERATIONS, EMBODY A SIMPLISTIC SOLUTION TO A COMPLEX PROBLEM: MONITORING TEMPERATURE VARIATIONS, A CRITICAL ASPECT IN VARIOUS INDUSTRIAL CONTEXTS.



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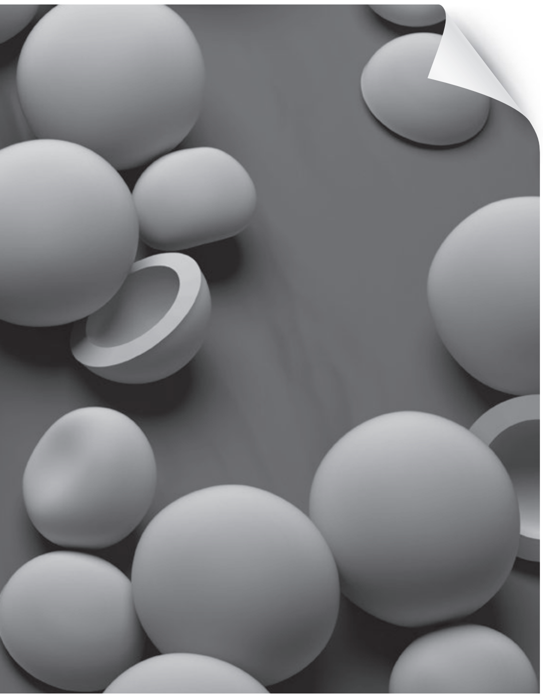


THE SOPHISTICATION OF ODSR LIES IN ITS SIMPLICITY – BY STEADFASTLY FOCUSING ON OPERATIONAL FEEDBACK AND ALIGNING STRATEGIES ACCORDINGLY, IT NEGATES THE NEED FOR OVERCOMPLICATED MANAGEMENT PROGRAMS.

Thermochromics: Simplifying Complexity

Consider an industrial scenario where machinery is prone to overheating in a circumstance that jeopardizes equipment longevity and poses potential safety risks. Here, the intricacies of monitoring numerous machinery parts for temperature anomalies can be laborious and error-prone. Thermochromic materials provide a straightforward answer. By altering their color in response to temperature changes, just like a warning light on a vehicle dashboard, they offer an immediate visual cue, alerting operators to potential overheating issues. Thus, a potentially complex problem is mitigated with a seemingly simplistic solution.

Simplicity Steering Effective Solutions

As thermochromic solutions navigate the intricacy of temperature management with utmost simplicity; ODSR navigates through the elaborate pathways of asset management with a streamlined focus: prioritizing operational insights. ODSR does not entangle itself in unnecessary complexities. Instead, it pivots towards ensuring that the feedback and experiences of those interacting with the assets – he operators – are centralized in crafting solutions.

ODSR demonstrates that equipping operators with the requisite knowledge and ensuring a conduit for channeling their feedback into management and design strategies simplifies the intricacies of maintaining and enhancing asset safety and reliability. The sophistication of ODSR lies in its simplicity – by steadfastly focusing on operational feedback and aligning strategies accordingly, it negates the need for overcomplicated management programs.

Seamless Integration of ODSR and Thermochromics

There lies a coherent synergy in the embrace of thermochromics within an ODSR framework. The straightforward feedback provided by thermochromic materials – the visual indicator of a color change – is effortlessly interpreted by operators. This direct feedback becomes an invaluable input within the ODSR program, wherein such insights are pivotal in shaping asset management and design strategies.

Conclusion

As industries evolve and technologies advance, there's a propensity to delve into complex solutions. However, as demonstrated by the ODSR framework and examples of thermochromic solutions, simplicity can steer us towards the most effective solutions. By minimizing complexity and anchoring solutions in simplicity, organizations can navigate the maze of asset management with enhanced clarity, efficiency, and efficacy. The ethos of the KISS principle, mirrored by ODSR and thermochromics, thus stands tall as a reminder that simplicity and sophistication can coexist harmoniously, driving robust solutions to complex problems.

For more information on thermochromic solutions visit: https://iriss.com/safe-connect-thermochromic-solutions/

Gerhard Salge

Photo: Hitachi Energy

Interview with **Gerhard Salge**

Chief Technology Officer at Hitachi Energy

> Flexibility is the answer for the power system - either to prevent or limit the consequences of those situations under normal operation and planned disturbances.

Alan Ross: My guest today is Gerhard Salge. Gerhard is the Chief Technology Officer of Hitachi Energy. Gerhard, I feel like I know you even though we've only met once. Thank you for joining us. Welcome!

Gerhard Salge: Thanks, Alan, for having me. I'm really looking forward to this discussion with you today.

AR I want to start off with something that I don't know if you wrote or somebody from the company, but it's in your LinkedIn profile, and it says, "Ensuring the timely build-out of power grid infrastructure will be a key enabler in accelerating the global energy transition. This urgent transformation will ensure effective integration of renewables and drive resiliency and flexibility of the power system." You're the first person that I've talked to who really talks about *flexibility* rather than *resiliency and reliability*. Let's start there. When you say *flexibility*, what do you mean?

GS Yes, I think that's a very good starting point, Alan. What we have been seeing is that the term flexibility is used more and more, across the world in various variants. We wanted to bring clarity into that as much as possible. There are also aligned discussions in CIGRE, IEEE, and other organizations on that. What we call *flexibility* is any operational timeline, from milliseconds to years, but also any normal operation and any hypothetical situation that you are planning for, which is usually the reliability part, as you just mentioned. *Resilience* is that part that you don't naturally plan for as a potential operational extreme situation. We have recently seen more and more examples of those resiliency situations. The pandemic was definitely one such situation, but also the recent extreme weather events that are unfortunately becoming more and more frequent. These are not the norm from a power system operational perspective.

That is when the active reaction of a power system is tested in terms of resilience.

TenneT's 2GW Platform.
Photo credit: TenneT

As such extreme events are becoming more and more frequent, we have actually started discussions on whether some of the resiliency topics have now become part of the reliability topics because they are unfortunately becoming the norm. Flexibility is the answer for the power system - either to prevent or limit the consequences of those situations under normal operation and planned disturbances.

AR That is the best description of where we are in the world today that I've heard so far. We are now adjusting to chaos: Extreme weather events, a pandemic, a war. We're adapting to those things and we're taking creative steps to adapt to the chaos. We're trying to anticipate and adapt to the extent that we can. That seems to be the biggest difficulty for the utility engineer, the planning department, or the development department. In these circumstances, how do you plan for flexibility in the grid?

GS Flexibility has four dimensions: Generation, demand, storage, and an active transmission and distribution system. That's important. Not just a passive system, but an active controllable system. When you want to create the best possible flexibility, you need to have all these four dimensions in balance. If you create one weaker dimension, you have defined the bottleneck of the total system. It means that on the power generation side, you can create flexibility through the complementarity of power generation types, locations, and so on. On the demand side, it's the same. You can create flexibility by having the consumers become "prosumers" where you can deal with them in a flexible way by either ramping up and down the demand profiles or even by completely disconnecting and reconnecting them after some time without losing the power/electricity supply to those customers.

Then, you have this combination of the controllable transmission and distribution

system, including storage. Here, the controllability in the distribution and transmission system comes with digital technologies to a large extent. This is the foundation, especially in combination with most modern power electronics, where you can control power flow, and contribute to inertia, by actively working in the system involving the fourth dimension, which is storage. And here again, the flexibility comes with complementarity. You have batteries all over the place, sometimes more centralized, sometimes decentralized, providing from very short injections of seconds to minutes to even several hours of support to the power system. But you also have other types of long-term energy storage like pumped hydro, where all of this together creates total system flexibility.

AR In September, I was at the RE+ conference doing live interviews. That event was primarily about solar and storage coming together. There I really saw for myself how all of the renewable energy affects the generation side. Storage in turn (positively) affects renewable energy.

On the demand side, you mentioned the "prosumer". My son has an electric car and solar on his roof, and as soon as he can talk me into giving him the money, we're going to put in a power wall. So, he is becoming flexible.
You have flexibility at the generation side and at the prosumer side, with storage being some of the common denominators along the way.
You mentioned storage briefly earlier, but where does it play a role, as you see it, in this whole flexibility/ sustainability/ resilience?

GS I'll start with the tremendous rise of solar in combination with storage, and in many cases, battery storage which you just described. Everyone understands that solar comes with a mid-day peak, and together with storage can be used in the best possible way at the lowest cost. On the generation side, such combinations help avoid curtailments and can be used as a buffer in case of an oversupply during

peak times, and it can delay the up-and-down ramping in the power system of all the solar-based generation. It allows for that harvested energy to be distributed over a much longer timescale, also hours after sundown.

> **You can create flexibility by having the consumers become "prosumers" where you can deal with them in a flexible way by either ramping up and down the demand profiles or even by completely disconnecting and reconnecting them after some time without losing the power/electricity supply to those customers.**

A really effective solar utilization only comes together with a strong connection to the total power system. In order to integrate that amount of power and energy into the system, and distribute it to the demand locations, which can be close or far away, you need a well-functioning and controllable transmission and distribution system. Without such a strong backbone grid, you cannot make use of time zone shifts, for example, where you have different peak times of solar generation, but also demand. And that is maybe the most prominent and illustrative example where you see the importance of the combination of solar generation with embedded HVDC transmission, which we are doing more and more across the world in power systems. So, you are basically enabling the power system to shift across time zones, potentially across climatic zones, the effective utilization of the best solar places, providing power and clean energy to the demand centers, and as previously described, in combination with storage over a much longer time throughout the day than just the mid-day peak.

Photo: Hitachi Energy

A really effective solar utilization only comes together with a strong connection to the total power system.

Wind power must also be mentioned here, as wind and solar usually complement each other very well. So, inside a power system, a renewable generation mix of solar and wind gives a very healthy complementation. With the combination of battery storage plus other types of longer-term storage (e.g., pumped hydro), you have a fantastic combination that the power system can leverage. You have this well-balanced controllable transmission and distribution system across the flexibility parameters.

Inside a power system, a renewable generation mix of solar and wind gives a very healthy complementation. With the combination of battery storage plus other types of longer-term storage (e.g., pumped hydro), you have a fantastic combination that the power system can leverage.

AR Everything that you're talking about, if we could just implement it all, I think we would all feel better about where we are. You and I are going to do another interview soon because I realized something as you were talking about where we are. I see that as a strategy. This is what we need to do. I think we need to also look at some of the implementation. So, there's strategy, then there's tactical implementation. I'd love to get deeper into that with you now, but it will have to wait until next time.

Before we say goodbye now, I'd like to quickly go back to something. You used the term "the hardening of the grid". I need you to talk about the hardening of the grid in terms of how it relates to everything that you just mentioned.

GS Now, the grid really needs to be resilient and not just against what has been planned for, but also the unplanned. Those unplanned factors differ across the world. That's why we need to have hardening. We also need equipment that is resilient against potential unplanned attacks, weather conditions, or anything that may physically challenge the assets.

Additionally, all digital technology must also be hardened or made resilient against cyber threats and anything that may come in terms of a physical threat, such as an intrusion into substations. Hence, it's important that we always look at a combination of physical and digital aspects when talking about hardening and resilience. That is crucial. That's why we at Hitachi Energy develop those concepts with our customers and partners together. We are always looking at the holistic picture, the same as we do at the power system.

It's important that we always look at a combination of physical and digital aspects when talking about hardening and resilience. That's why we at Hitachi Energy develop those concepts with our customers and partners together.

When we plan the installation of HVDC lines, STATCOM, and other solutions and services with our partners and customers around the world we look at it holistically in order to make the designs fit for the future. Because I think that is really one critical consideration that should be applied in the power system. What you invest in today will see a lot of changes in the next years and next decades. Take the most modern, most future-fit design, equipment, systems, and services so that you are equipped as best as possible for all the changes, which will come over the next years.

AR I'm going to give you a new title. I'm going to call you the Doctor of Holistic Grid Flexibility. You have avoided the idea of fixes to this and fixes to that and have looked at a holistic solution. I'm glad Hitachi Energy is doing the same thing.

This has been a brilliant interview. I appreciate it.

GS Thank you very much, Alan. It's the same on my side. It was a pleasure to be here. Since electricity is becoming the

Photo: Hitachi Energy

backbone of the entire energy system, we cannot do enough to make this as secure, reliable, flexible, and affordable as possible.

AR That's our next interview right there: "Why electricity is the backbone of the entire energy system". We've got to come back on that one, Gerhard. Thank you so much for being here today, I appreciate it.

GS Thank you, Alan, it was a great pleasure!

TRANSFORMER ON-LINE BUSHING MONITORING SYSTEM EXPERIENCES

Transformers are the most important assets in the power network. Increasing number of electrical vehicles, demand for additional charging stations, installation of heat pumps impact the infrastructure.

Transformers are the most important assets in the power network. During the last few years, the share of electrical energy generated from photovoltaic and wind power plants was continuously growing. Power network configuration, energy flow and the transformer role change. Increasing number of electrical vehicles, demand for additional charging stations, installation of heat pumps impact the infrastructure. AC inverters used for converting the DC voltage to AC increase the risk of damage to the equipment insulation system. The main negative aspects of the converters are the harmonics (deformation of sinusoidal voltage) and their impact on the degradation of the insulation system.

Based on the CIGRE technical brochure 642, "Transformer Reliability Survey"[1], almost 18% of all failures documented for transformers operated in substation can be tracked down to the malfunction related with transformer bushings. Additionally, it is important to mention that bushing failure leads in most cases to fire or explosion of the transformer (37% of all critical failures with explosion or fire). The above numbers show how critical and important proper maintenance of this transformer component is. To ensure functionality and on time service planning several on-line monitoring systems are used what with periodical testing (specified by the bushing manufacturer) increase system reliability significantly [2].

Introduction

In the previous years, several monitoring systems based on different measurement and evaluation methods were developed to control capacitance and dissipation factor (power factor) – the two most critical parameters of transformer bushings. Change of these bushing parameters during transformer operation time delivers essential information of the insulation system state and is specified by the manufacturer.

The bushing monitoring evaluation results are important for future decisions related to transformer operation. The correct measurement method and accuracy of the whole bushing monitoring system (C or/and tan delta) is a most important parameter of such a system. Several external parameters such as used bushing coupling units and its internal components (capacitors or/and resistors with temperature dependency), voltage and current signal filters, algorithms performing calculation (air temperature and moisture impact) and evaluation (external reference, voltage comparison etc.) as well as visualization of the results impacting the overall system usability. It is important to mention that the allowed capacitance and dissipation factor change depend on the type and operating voltage of the bushing. One of the most common and sufficient on-line bushing monitoring methods is a voltage measurement (coupling on the test or voltage tap) with or without comparing to external reference signal (voltage transformer) [3].

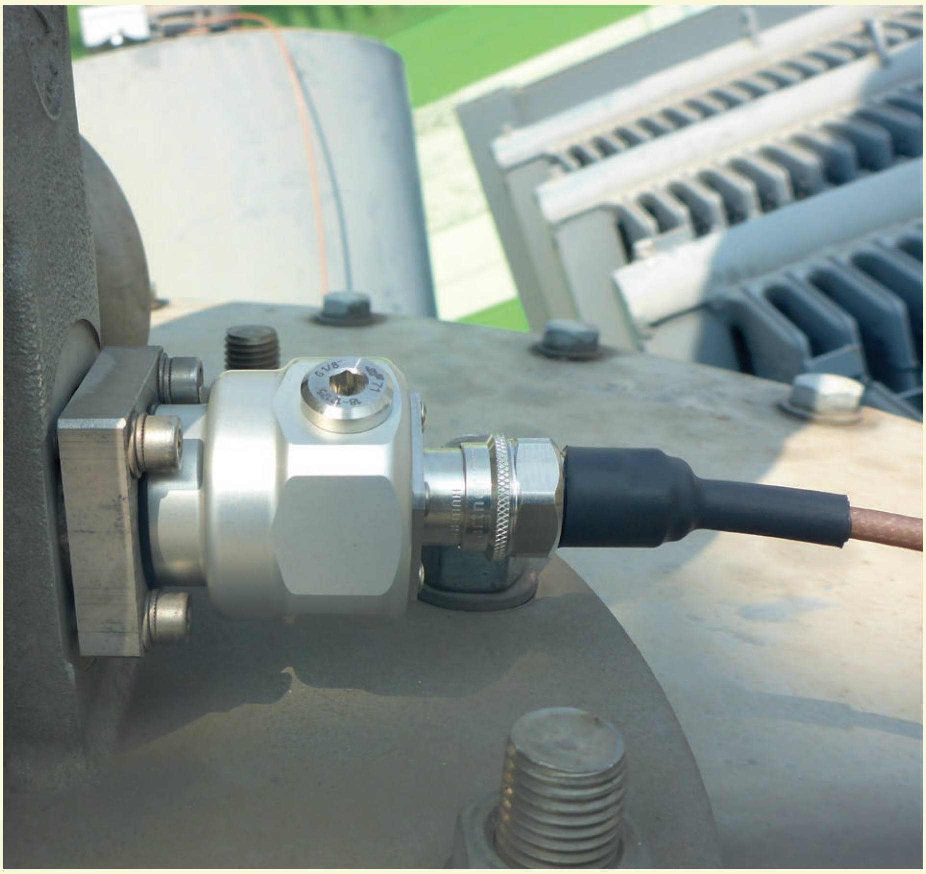


Photo: Maschinenfabrik Reinhausen GmbH

Transformer Bushing and On-Line Monitoring

The main function of the transformer bushings is to transfer current at defined potential to the winding through an opening in the transformer tank. Condenser-type bushings are used for higher voltages, reducing radial and axial voltage stresses while minimizing size. Bushings are manufactured by wrapping paper or synthetic material on a central conductor (for example aluminum tube), with separate electrodes (thin metal foil, conductive paper, or paint) of defined length and diameter.

Typically, the last electrode relates to measuring tap (called test or voltage tap depending on the type and function) creates two main capacitances that can be measured:

C_1 – is a HV capacitance between the central electrode and the tap, $C_1 = C_{e1} + C_{e2} + ... + C_{en}$ where the C_{e1}, C_{e2}, C_{en} are the serially connected elementary condensers.

C_2 – is a LV capacitance between the tap and the flange on ground potential (in operation this capacitance is short-circuited to ground).

The main function of the transformer bushings is to transfer current at defined potential to the winding through the transformer tank. Condenser-type bushings are used for higher voltages, reducing radial and axial voltage stresses while minimizing size.

Depending on the insulation material used in manufacturing we can distinguish between the following types:

RBP – Resin Bonded Paper
OIP – Oil Impregnated Paper
RIP – Resin Impregnated Paper

For all the above bushings the paper is used as an insulating material. New development also introduces synthetic materials with higher operating temperatures and lower humidity absorption instead of paper.

RIS – Resin Impregnated Synthetic
RIF – Resin Impregnated Fiber

The bushing coating or housing (weather sheds) can be made from porcelain or silicon rubber. Manufacturing technology impacts the importance of the monitored parameters. For example, the capacitance C_1 of the RBP compared to the RIP and OIP is affected by the oil penetration into the main structure of condenser body. Change of C_1 can be observed even if there is no short-circuited elementary condenser situation. RIS bushing can keep dissipation factor on constant level.

The most efficient way to estimate bushing condition based on the on-line monitoring is to control the change of the capacitance C_1 and the associated dielectric dissipation factor (tanδ) or power factor (PF - sinδ). It is proven that humidity and the ageing process are impacting capacitance only at higher temperatures. A short circuit between elementary condensers will increase the capacitance independent of temperature. The change in the dissipation factor and power factor is temperature-dependent. Increase of tanδ indicates higher loss in the bushing's insulation system and is often caused by introduction of moisture or ageing process.

Limits for the change of C_1 and tanδ are depending on the system voltage and technology used for bushing construction. The approximate capacitance changes corresponding to short-circuited elementary condensers are shown on the next page in Table 1.

Table 1: Examples of approximate capacitance change of the C_1 for short-circuited elementary condensers [4].

Um [kV]	RIP capacitance change [%]	OIP capacitance change [%]
72,5	12	8,8
123	7,1	4,8
145	6,3	3,9
170	5,3	3,4
245	4,2	2,7
300	2,9	2,4
362	2,4	2,1
420	2,2	1,7
550	1,9	1,3
800	1,3	0,9

Um – maximum operating voltage

More accurate information regarding the number of elementary condensers needed for better calculation of the capacitance change should be provided by a bushing manufacturer. The information is essential to set warnings and alarms limits to the correct level.

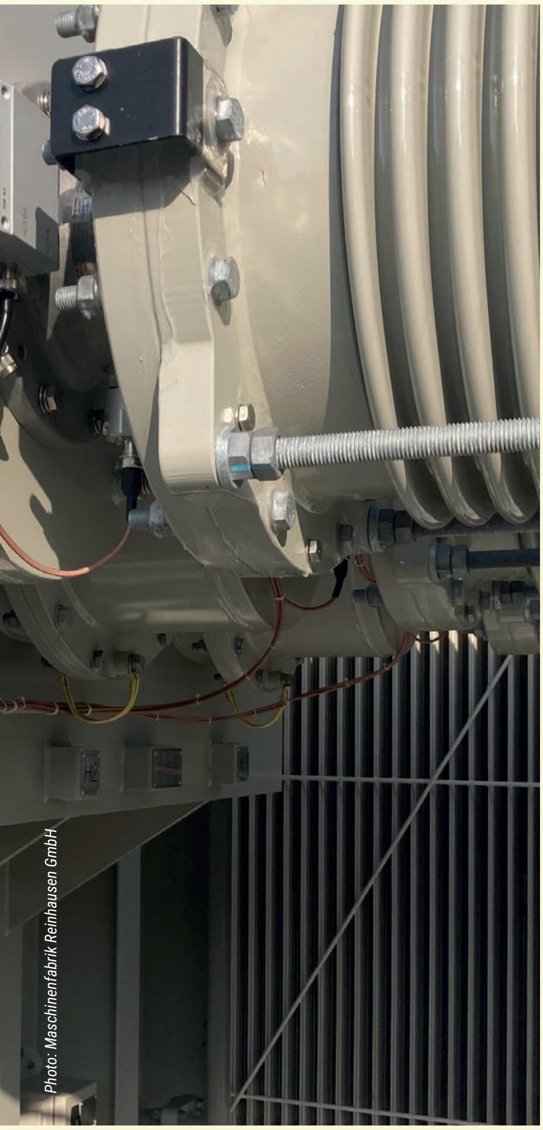


Photo: Maschinenfabrik Reinhausen GmbH

Compared to the capacitance the tanδ measurement is much more sensitive to external factors (temperature, weather condition) due to the small value of angle δ. Bushing condition evaluation based on tanδ measurement depends on the bushing insulation type and construction. Two evaluation methods can be applied: based on the specified tanδ value or a relative tanδ change.

Table 2: Limits for the evaluation of the power factor for bushings depending on technology used [4].

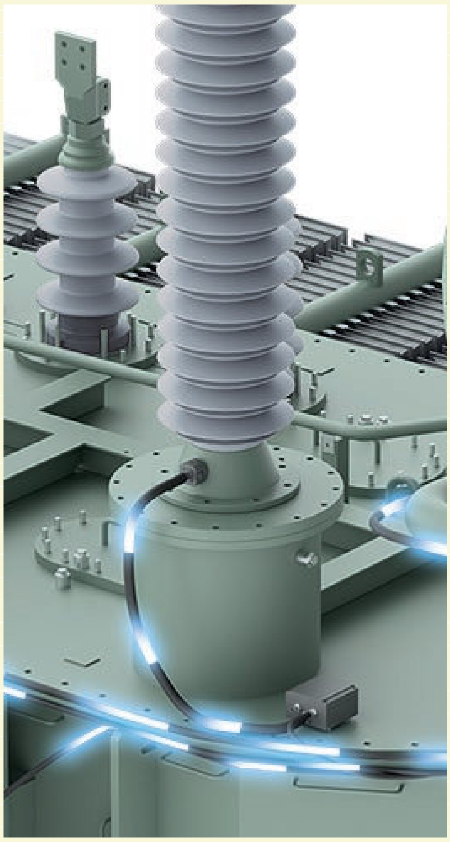
Standards	RIP	OIP	RBP
Tan Delta (IEC 60137)	< 0.7 %	< 0.7 %	< 1.5 %
Power Factor (IEEE C57.19.01)	< 0.85 %	< 0.5 %	< 2 %
Typical values aged 50/60 Hz (according to CIGRE Brochure 445)	< 0.5 %	< 0.5 %	1.0 %

Table 3: Accuracy for capacitance and tanδ measurement for different systems [5].

Accuracy	Tan Delta or Power factor	Capacitance	Leakage current	Phase
System A	± 0.035 %	± 0.2 %	0,1 %	± 0.01°
System B	1 %	0,1 %	0,1 %	0.01°
System C	0,05 %	1 %	1,5 %	0.1°
System D	n.a.	0,20 %	0,1 %	n.a.
System E	Δtanδ ± 0.01 %	± 0.04 %	n.a.	n.a.
System F	Δtanδ: < 0.001 (0.01 %; ± 0.1 mrad)	< 0.7 %	< 0.7 %	< 1.5 %
System G	0.05 % + VT error	± 2 pF + VT error	± 1 mA	n.a.

Monitoring systems offered on the market provide technical information regarding accuracy of the capacitance and tanδ measurement. Examples of an accuracy for different monitoring systems can be found in Table 3.

Monitoring systems offered on the market provide technical information regarding accuracy of the capacitance and tanδ measurement.



Understanding of the basic parameters makes the comparison and preparation of monitoring system specification simple and clearer. The focus should be put on the essential parameters like power factor and capacitance. These two parameters are well described and the limits for different bushing technology are known.

The accuracy of capacitance should be defined as percentage change of the measured capacitance what correspond to the change if one conducting layer will be short-circuited what is depending on the system voltage and bushing type. For example, accuracy of 1% for the capacitance change can be not enough for the higher voltages > 400 kV in case of OIP bushing type but sufficient for < 170 kV for RIP bushing type.

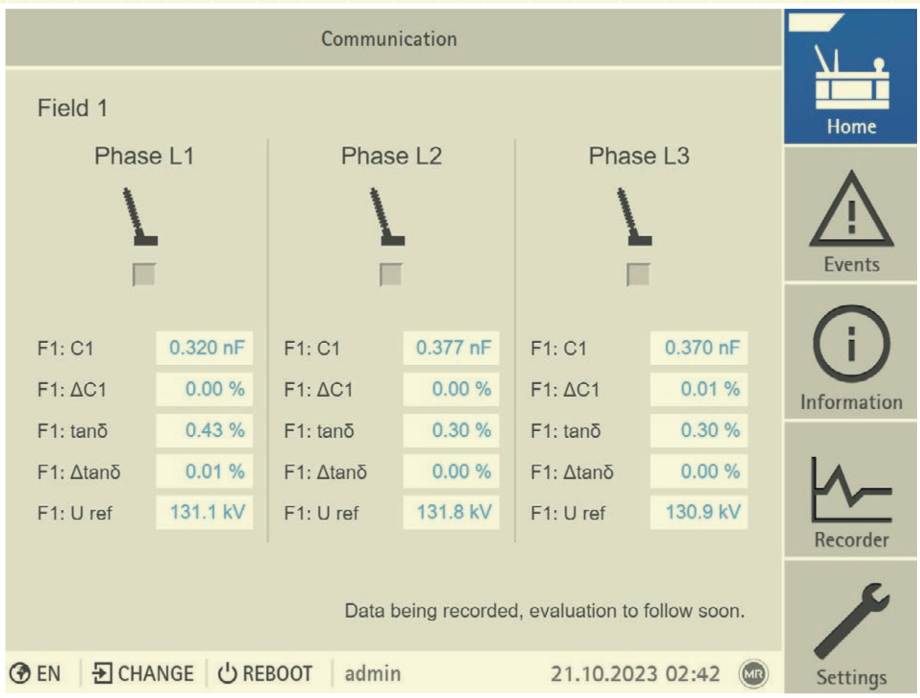
The power factor or tanδ should also be defined as accuracy of the percentage change. For example, the new OIP bushing with tanδ = 0,5% shows starting aging process if the values go to the 0,7% [5].

Bushing On-Line Monitoring Challenges

Transformer on-line bushing monitoring system can be installed from the beginning of operation or as a retrofit. In many cases, based on experience, bushing failures appear during the first years or after many years in service. Such failures can be triggered by bad condition of insulation because of moisture ingression or oil leakage, incorrect handling, or lack of regular service.

On-Line Monitoring constantly delivers necessary information allowing proper operation and on-time maintenance (if necessary) of a transformer bushing. It is important that such a system can work in each environmental condition and is not affected by external noise providing measured data with sufficient accuracy.

Figure 1: Visualization of the on-line bushing monitoring.

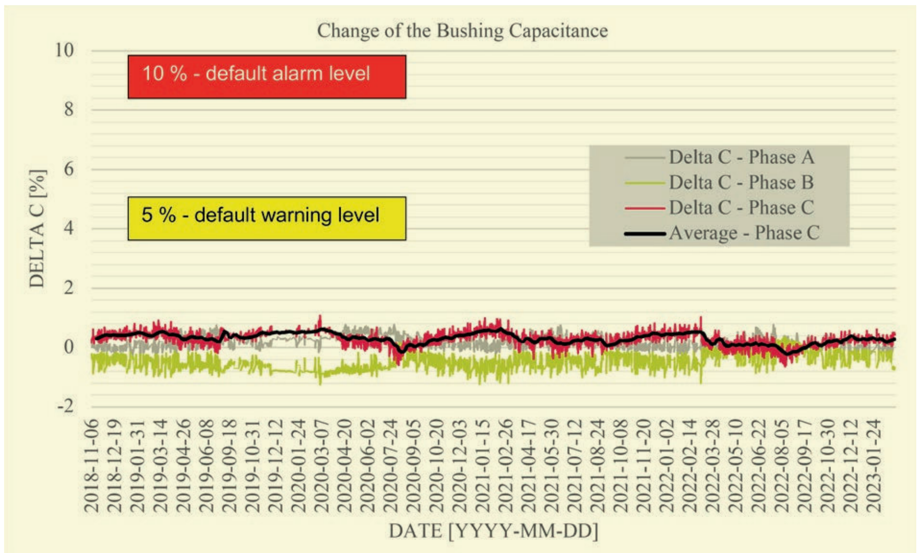


Based on experience, Maschinenfabrik Reinhausen GmbH has developed a product that meets this fundamental principle. MSENSE®BM uses a dual reference voltage method. The bushing voltage signal is compared with voltage reference from the same phase measured on the voltage transformer. The second comparison, based on the patented method, is made with the signal from the adjacent phase (phase A with B, B with C and C with A). The influence of the network fluctuation in amplitude and phase shift, as well as external interference (sun, rain, etc.), can therefore be effectively eliminated while maintaining the required measurement accuracy.

Example 1 – Stable installation.

In the figure below an example of bushing monitoring signals evaluation recorded during four years in operation is shown. No significant deviation in measured of the capacitance were observed. The signals remain stable (approx. 0,5% oscillation) and do not cross the warning and alarm level which was set respectively for 5 and 10%.

Figure 2: Change of the bushing capacitance over long installation period.



Looking more closely at the voltage measurement for bushing and reference signals, it is easy to observe that the fluctuation of the voltage is identical. The same amplitude of both voltages indicates no change in the bushing capacitance. Signal accuracy is sufficient and stable.

Figure 3: Voltage comparison for phase A (bushing and reference signal).

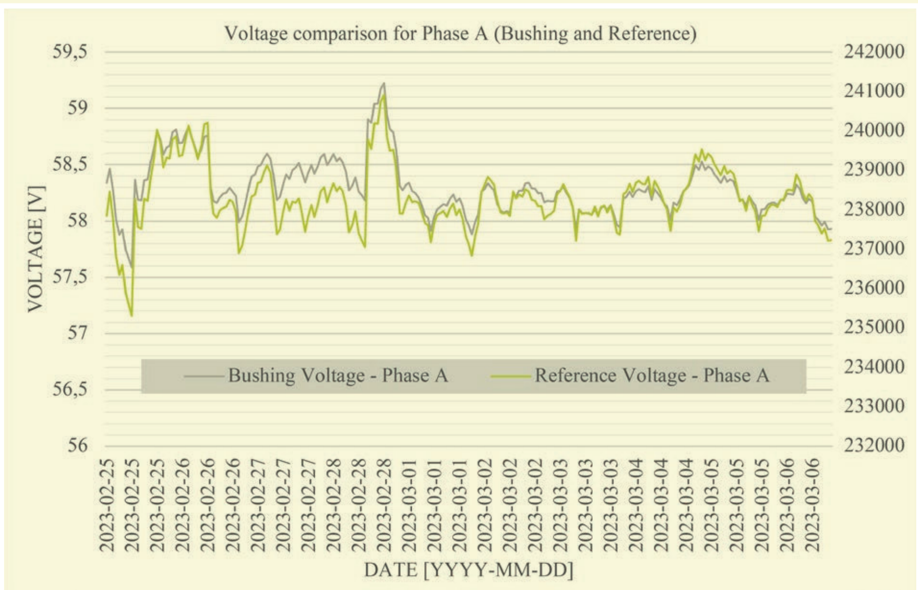
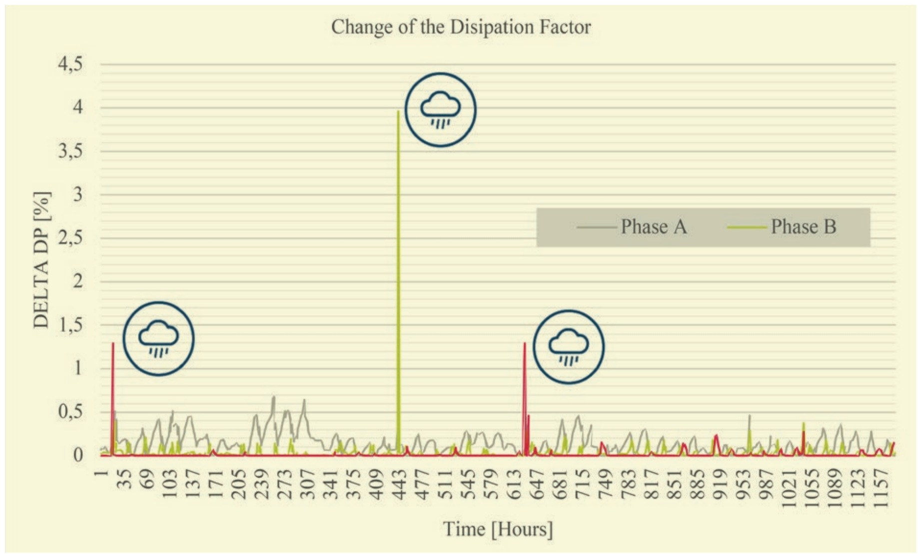


Photo: Maschinenfabrik Reinhausen GmbH

Example 2 – Impact of the pollution of the bushing surface

If the bushing monitoring installation site is impacted by high pollution, the system can record short "spikes". This behavior can be observed especially for dissipation factor measurement and is caused by discharges on the bushing housing surface. The correlation of the measured signal with historical information regarding weather conditions can be easily observed. Signal with "Spikes" was detected only during raining season and back to previous level after short time. In that case different mechanical construction of the bushing housing is negatively impacting the signal recording. To avoid false alarms additional algorithms in MSENSE®BM for signal evaluation are implemented.

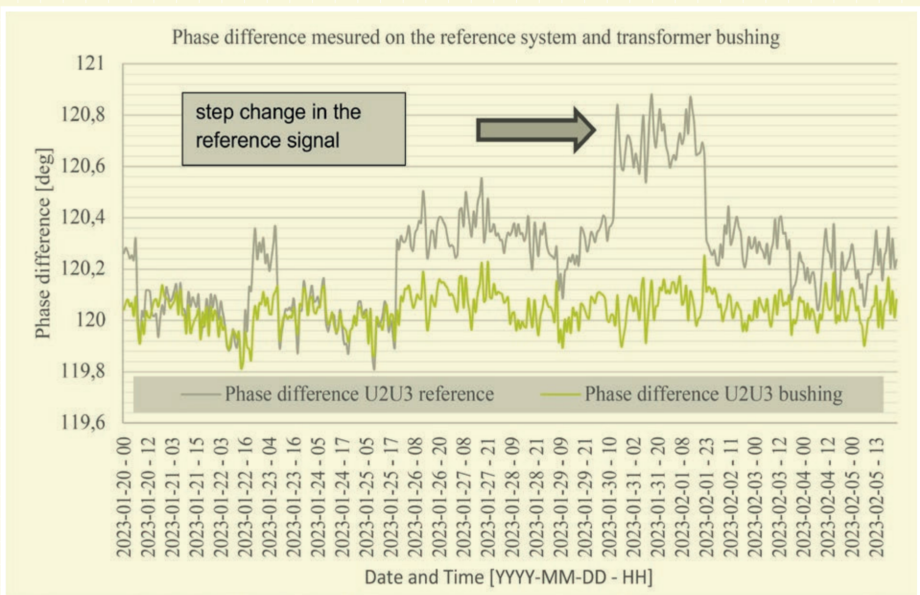
Figure 4: Change of dissipation factor due to weather condition.

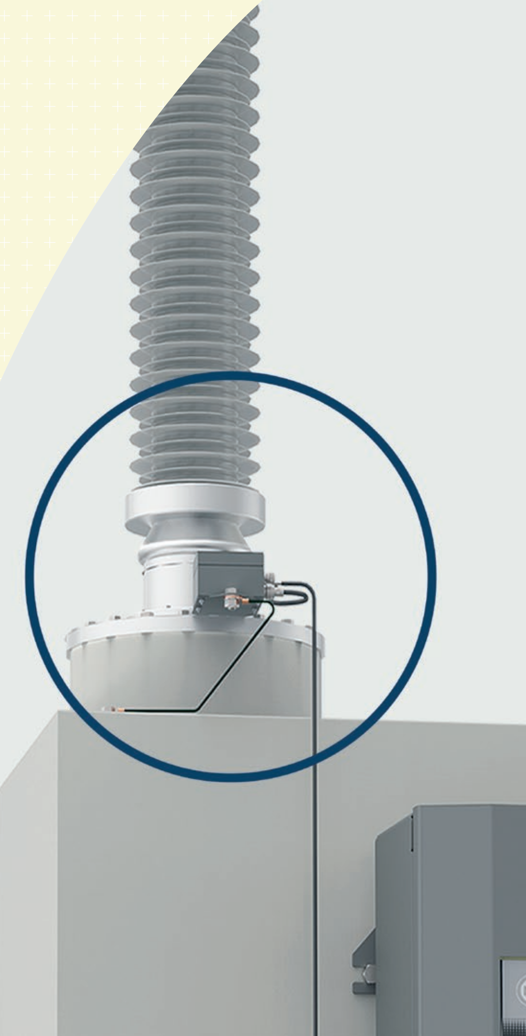


Example 3 – Reference signal

Simple comparison of the reference voltage or phase shift measurement with the bushing reading can also impact signal evaluation. In the case below, a simple monitoring system can generate false alarms during changing of the busbar connection in the substation. For that special configuration, the signal from the voltage transformer was distorted for phase shift which was confirmed with external measurement. Evaluation of the recorded signals shows stable signal for bushing phase displacement and step changes in signal measured on voltage transformer. Implementation of additional algorithm in MSENSE®BM allow to detect that change to avoid generation of the false alarms.

Figure 5: Phase shift difference for unstable voltage transformer.





The on-line bushing monitoring systems help maintain safe transformer operation and schedule of maintenance activities on demand. By choosing the most suitable measurement method in combination with implementation of evaluation algorithms, MSENSE®BM provides constantly correct information with the required accuracy.

Conclusion

The on-line bushing monitoring systems help maintain safe transformer operation and schedule of maintenance activities on demand. Depending on the measurement method used, different accuracy can be achieved in estimating changes in capacitance and dissipation factor. Information about the type of bushing installed on the transformer, system voltage, network stability and location are essential to correctly evaluate the measured signal.

By choosing the most suitable measurement method in combination with the implementation of evaluation algorithms, MSENSE®BM provides constantly correct information with the required accuracy. Integration with ETOS® (Embedded Transformer Operating System) makes it easy to install and use this precise and cost-effective solution for on-line bushing monitoring system.

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Janusz Szczechowski is a Product Manager of Maschinenfabrik Reinhausen GmbH based in Germany, with more than 20 years of experience in research and development of power transformer monitoring and test technologies. Product development and research projects handled includes power transformer bushing monitoring, partial discharge measurement systems and evaluation methods, high voltage testing for factory and on-site mobile applications, maintenance and condition assessment.

Photo: Maschinenfabrik Reinhausen GmbH

Powering the Future:
Exploring the Future of Power Distribution Technologies

by **Binesh Asok Kumar**

AC EMERGED AS THE DOMINANT TECHNOLOGY FOR POWER DISTRIBUTION, THANKS TO ITS ABILITY TO TRANSMIT ELECTRICITY OVER GREATER DISTANCES WITH LESS LOSS.

Binesh Asok Kumar is a technology and engineering leader, who works as a Technical Project Lead at Atom Power Inc, in Charlotte, North Carolina, USA. His background is in electrical engineering with over a decade of experience in R&D and product development in the power and energy domain. He is an active IEEE senior member and serves in several leadership roles within IEEE.

A BRIEF HISTORY

The Early Days: DC Power Distribution

The story of power distribution technologies begins with Thomas Edison and his famous Pearl Street Station, which opened in 1882 in Manhattan, New York. This was one of the first commercial power plants in the world and was powered by direct current (DC). Edison's vision was to bring electricity to the masses for lighting and, eventually, other applications. DC had several advantages, including simplicity and reliability. However, it had a significant drawback - it couldn't be transmitted over long distances efficiently. As a result, DC systems were limited to small geographic areas, and multiple power plants were needed to serve a city.

The Rise of Alternating Current (AC)

Nikola Tesla's alternating current (AC) system allowed for the efficient transmission of electricity over long distances, making it possible to establish centralized power plants that could serve entire cities. Tesla's contributions laid the foundation for the modern electric grid. The late 19th century saw the famous "Battle of Currents" between Edison, who championed DC, and George Westinghouse, who backed Tesla's AC system. Ultimately, AC emerged as the dominant technology for power distribution, thanks to its ability to transmit electricity over greater distances with less loss.

Photo: Shutterstock

The Birth of the Electric Grid

The success of AC led to the establishment of the first electric grids. These grids interconnected power plants, enabling electricity to flow from generating stations to homes and businesses across vast regions. By the early 20th century, electric grids became more extensive, allowing for greater electrification. Transformers played a critical role in AC power distribution. They allowed voltage to be efficiently stepped up for long-distance transmission and stepped down for safe consumption in homes and businesses. This was a significant advancement that improved the overall efficiency of electric grids.

Electrification and Industrialization

As power distribution technologies evolved, they had a profound impact on society. Electricity transformed homes, industries, and cities, providing new opportunities for economic growth and innovation. The electrification of urban areas led to the development of various electrical appliances and devices, making life more convenient. Power substations helped manage voltage levels and improve the reliability of electricity distribution.

Electricity also became a primary source of energy for industries. Factories, manufacturing plants, and other businesses benefited from the reliability and flexibility of electrical power. This drove increased demand for electricity and further expansion of power distribution networks.

POWER SUBSTATIONS HELPED MANAGE VOLTAGE LEVELS AND IMPROVE THE RELIABILITY OF ELECTRICITY DISTRIBUTION.

Challenges and Innovations in the Mid-20th Century

While the electric grid brought immense benefits, it also exposed vulnerabilities. Natural disasters, equipment failures, and other disruptions could lead to widespread power outages. This prompted a need for more resilient and reliable power distribution technologies.

To address these issues, protective devices like circuit breakers and fuses were developed. These devices helped prevent damage to the grid and ensured a more reliable power supply. Additionally, advancements in materials and insulation improved the safety and efficiency of power distribution systems.

Modernization and the Smart Grid

The late 20th century and early 21st century saw a digital revolution that extended to power distribution technologies. This period marked the transition to the smart grid, a concept that combines advanced digital technology with the electric grid to improve efficiency, reliability, and sustainability.

One of the key components of the smart grid is the deployment

Photo: Shutterstock

of smart meters and advanced metering infrastructure (AMI). Smart meters allow for real-time monitoring of electricity usage and provide consumers with greater control over their energy consumption. Utilities benefit from better data for managing the grid and responding to outages.

ONE OF THE KEY COMPONENTS OF THE SMART GRID IS THE DEPLOYMENT OF SMART METERS AND ADVANCED METERING INFRASTRUCTURE (AMI).

The smart grid also enables the integration of renewable energy sources like solar and wind power. This flexibility in power generation supports sustainability goals and reduces our reliance on fossil fuels. Grid operators can balance supply and demand more efficiently, making renewable energy a more significant part of the energy mix.

The Future of Power Distribution Technologies

The future of power distribution technologies holds the promise of transforming the way we generate, transmit, and distribute electricity. With the increasing global demand for energy, coupled with the urgent need to mitigate climate change, there is a growing imperative to modernize and revolutionize power distribution systems.

Transition to Renewable Energy Sources

One of the most significant shifts in power distribution technologies is the transition from fossil fuels to renewable energy sources. Renewable energy offers a clean and sustainable alternative to traditional coal and natural gas-based power generation. In the future, we can expect to see a more significant integration of renewable energy sources into the power grid.

Solar Power

Solar photovoltaic (PV) technology has experienced tremendous growth in recent years. Advancements in solar cell efficiency and affordability have made solar power a viable option for widespread adoption. Solar farms, distributed solar installations, and building-integrated photovoltaics all contribute to the diversification of the energy mix.

Wind Power

Onshore and offshore wind farms are becoming more common, harnessing the kinetic energy of wind to generate electricity. Innovations in wind turbine design are improving the viability of wind power as a primary energy source.

Hydropower

Hydropower has long been a reliable source of renewable energy, but innovations in small-scale and low-impact hydropower technologies are making it more accessible and environmentally friendly. These innovations allow for the installation of small hydropower systems in a wider range of locations, reducing the environmental impact.

The shift to renewable energy not only reduces greenhouse gas emissions but also introduces new challenges to power distribution. Renewable energy sources can be intermittent, depending on weather conditions, which requires the development of advanced energy storage technologies and smart grid systems.

Energy Storage Technologies

Energy storage is a critical component of the future power distribution landscape. It enables the efficient utilization of renewable energy and addresses the intermittency issues associated with sources like solar and wind. Several energy storage technologies are emerging as key players in the transition to a more sustainable grid.

Lithium-Ion Batteries

Lithium-ion batteries have become the go-to technology for energy storage. Their high energy density, fast charging capabilities, and decreasing costs make them ideal for residential, commercial, and utility-scale applications. Continued research and development are expected to enhance battery performance and longevity further.

Advanced Flow Batteries

Flow batteries, such as vanadium and zinc-bromine flow batteries, offer the advantage of scalability and longer cycle life. These technologies are well-suited for large-scale energy storage applications and are being explored for grid-level integration.

Supercapacitors

Supercapacitors, also known as ultracapacitors, provide rapid energy discharge and recharge. They have the potential to complement batteries by offering short-term, high-power energy storage solutions for grid stabilization and load balancing.

CAES

Compressed Air Energy Storage (CAES) systems store energy by compressing air and storing it in underground caverns or tanks. When electricity is needed, the compressed air is released and used to generate power. CAES can provide large-scale energy storage and help stabilize the grid.

Energy storage technologies will play a crucial role in grid resiliency, ensuring a continuous power supply and enabling the integration of renewable energy sources at a greater scale.

Smart Grids and Grid Management

The development of smart grids is another pivotal aspect of the future of power distribution technologies. A smart grid is an advanced electrical grid that incorporates digital communication and control systems to enhance grid efficiency, reliability, and sustainability.

AMI

Smart meters are a fundamental component of smart grids. They enable real-time monitoring of energy consumption and can communicate with both utility providers and consumers. Advanced Metering Infrastructure (AMI) allows for better demand management and more precise billing.

Photo: Shutterstock, Atom Power

Grid Automation

Automation and control systems enhance grid resilience by reducing the impact of faults or outages. These systems can isolate damaged sections of the grid and reroute power to minimize downtime. They also enable the integration of distributed energy resources, such as rooftop solar panels and electric vehicle charging stations.

Demand Response Programs

Demand response initiatives encourage consumers to adjust their energy usage during peak periods, helping to balance the grid and reduce the need for additional power generation. Smart grids make it easier for consumers to participate in these programs, ultimately lowering electricity costs and reducing strain on the grid.

Microgrids

Microgrids are self-contained electrical systems that can operate independently or in coordination with the main grid. They are particularly valuable during emergencies and outages, as they can provide localized power generation and distribution.

The development of smart grids and grid management systems is essential for accommodating the growing complexity of the energy landscape. They improve grid reliability, enable the integration of renewable energy sources, and allow for more effective energy management.

THE DEVELOPMENT OF SMART GRIDS AND GRID MANAGEMENT SYSTEMS IS ESSENTIAL FOR ACCOMMODATING THE GROWING COMPLEXITY OF THE ENERGY LANDSCAPE.

Electrification and Distributed Energy Resources

Another significant trend in power distribution technologies is the electrification of various sectors, such as transportation and heating, and the proliferation of distributed energy resources (DERs). These developments are reshaping the way we consume and distribute electricity.

Electric Vehicles

The electrification of transportation is gaining momentum with the growing adoption of electric vehicles. Electric Vehicles (EVs) not only reduce greenhouse gas emissions but also offer opportunities for vehicle-to-grid (V2G) technology, where EVs can store and supply electricity back to the grid during peak demand.

Heat Pumps

Electric heat pumps are replacing traditional heating and cooling systems in residential and commercial buildings. These systems are more energy-efficient and can be integrated into smart grids to optimize energy usage.

Distributed Generation

The rise of distributed energy resources, such as rooftop solar panels and small wind turbines, allows consumers to generate their own electricity. Excess energy can be sold back to the grid, contributing to a more decentralized energy system.

Electrification and the proliferation of DERs contribute to grid resilience and sustainability by diversifying the energy mix and reducing reliance on fossil fuels. However, they also require advanced grid management and control to ensure seamless integration.

The Rise of Solid-State Technology

Solid-state technologies in power distribution systems represent a paradigm shift away from traditional electromechanical devices like switches and relays. These solid-state components use semiconductor materials to control the flow of electrical current, providing numerous benefits that contribute to the optimization of power distribution.

Solid-state technologies have ushered in a transformative era in power distribution by replacing traditional electromechanical components with semiconductor-based devices. These solid-state components, including transistors, thyristors, and silicon-controlled rectifiers, have revolutionized the way electricity is controlled and managed within distribution systems.

The fundamental advantage of solid-state technologies lies in their efficiency and precision. They operate with minimal energy losses, significantly reducing waste and operational costs. Additionally, these devices provide precise control over voltage, current, and frequency, which is essential for maintaining the stability of electrical grids, particularly in the presence of variable renewable energy sources. Their reliability is also a game-changer, as solid-state components have no moving parts, resulting in longer lifespans and less frequent maintenance requirements. The speed at which solid-state technologies can respond to electrical events, within microseconds, is another crucial aspect of their effectiveness. This rapid response is essential for preventing equipment damage, minimizing downtime, and enhancing overall grid resilience. Applications of solid-state technologies in power distribution are diverse and ever-expanding, driving advancements in grid management and electrical infrastructure. Smart grids, for example, heavily rely on solid-state devices for real-time monitoring, fault detection, and efficient grid management. They enable automatic responses to changing conditions, thus improving grid reliability and performance. Moreover, solid-state technologies play a pivotal role in the integration of renewable energy sources. The variable nature of renewable sources like solar and wind necessitates advanced power electronics for efficient conversion and grid-friendly power supply. These technologies also find applications in critical infrastructure, such as data centers, where they ensure uninterrupted power supply and protect sensitive equipment from electrical faults.

Photo: Atom Power

Electric vehicle charging stations are another area benefiting from solid-state components, enabling efficient power conversion and rapid charging, thereby supporting the growing electric vehicle market. In summary, solid-state technologies are transforming the landscape of power distribution, enhancing efficiency, precision, and reliability, and contributing to the development of smarter, more resilient electrical grids.

SOLID-STATE TECHNOLOGIES HAVE USHERED IN A TRANSFORMATIVE ERA IN POWER DISTRIBUTION BY REPLACING TRADITIONAL ELECTROMECHANICAL COMPONENTS WITH SEMICONDUCTOR-BASED DEVICES.

Cybersecurity and Resilience

As power distribution technologies become increasingly digital and interconnected, the need for robust cybersecurity measures is paramount. The grid is vulnerable to cyberattacks that could disrupt power supply and compromise data integrity.

Advanced Cybersecurity

Power utilities and grid operators must invest in advanced cybersecurity measures to protect critical infrastructure from cyber threats. This includes encryption, intrusion detection systems, and continuous monitoring of network traffic.

Resilience Planning

Developing resilience strategies is crucial for minimizing the impact of natural disasters, physical attacks, and cyberattacks. This includes the creation of redundant infrastructure, emergency response plans, and backup power systems.

Grid Hardening

Reinforcing the physical infrastructure of the grid, such as transmission lines and substations, is essential to withstand extreme weather events and physical attacks.

Ensuring the cybersecurity and resilience of power distribution systems is a continuous challenge, as threats and vulnerabilities evolve over time. However, addressing these issues is vital to maintaining a reliable and secure power supply.

Conclusion

The evolution of power distribution technologies is a testament to human ingenuity and our ability to adapt to changing needs and challenges. From Edison's DC system to the smart grid of the 21st century, power distribution has come a long way, shaping the modern world and enabling countless technological advancements. As we look to the future, the continued development of smart grid technologies and a focus on sustainability will be essential for meeting the growing demands of our electrified world while addressing environmental concerns. The journey of power distribution technologies is far from over, and the next chapters promise to be just as exciting and transformative as those that have come before.

The future of power distribution technologies is defined by a commitment to sustainability, resilience, and efficiency. The transition to renewable energy sources, the development of advanced energy storage technologies and grid automation, and the electrification of various sectors are shaping the path forward. These developments not only reduce greenhouse gas emissions, but also enhance grid reliability and flexibility.

As we progress into this future, it is crucial to focus on ongoing research and development efforts. Innovations in materials, storage technologies, and grid management systems will play a pivotal role in overcoming the challenges associated with power distribution. Moreover, the integration of artificial intelligence and machine learning in grid control and prediction models will enable more precise and efficient energy management.

The future of power distribution technologies is a shift towards a cleaner, more resilient, and interconnected grid that can adapt to the changing energy landscape and meet the needs of a rapidly growing global population. To realize this vision, collaboration among governments, industries, and research institutions is essential. By working together, we can build a future where power distribution is sustainable, reliable, and adaptable to the challenges of the 21st century, ultimately contributing to a cleaner and more sustainable world.

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Michael Heyeck

Photo: Michael Heyeck

CIGRE United States

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Distribution gets the last dime and donut. We need to transform distribution, and regulators in the states really need to make sure that they're funding the distribution.

Interview with **Michael Heyeck**

Founder of The Grid Group LLC; **VP Finance & Treasurer** at CIGRE; **Chairman** of Westerville City Council

Alan Ross: I'm Alan Ross, the managing editor of APC Media and APC Technologies. We are at the CIGRE 2023 Grid of the Future Symposium, and these interviews are with the leaders at CIGRE and the industry. I hope you enjoy. My next guest is Michael Heyeck. You are a sole proprietor now of your own consulting group, but before that, you were with AEP for years. But first of all, you're an engineer.

Michael Heyeck: Yes.

AR How did you get into the industry? How did you decide to become an engineer? Because back in the day, it wasn't the sexiest thing to do, but you got involved in it.

MH Well, it was a sexy thing to do because I was born during the space race, putting a man on the moon.

That got me involved with engineering. I wanted to be a teacher, but my mother said, no, you should be involved in engineering.

I like math and science and stuff like that, but power engineering is electricity, utility work. That's public service. I'm glad I stepped into electrical engineering and into the utility business.

[ENGINEERING] WAS A SEXY THING TO DO BECAUSE I WAS BORN DURING THE SPACE RACE, PUTTING A MAN ON THE MOON. THAT GOT ME INVOLVED WITH ENGINEERING.

AR Were you with AEP your entire career?

MH Yes.

AR What did you do for AEP? What did you do when you started? What did you do when you left?

MH I was involved with transmission planning, and then I got involved with putting a budget system in, because I got an MBA as well. I was a budget director for AEP, then I got into transmission operations, and then I headed up transmission.

AR This is a significant problem today. We're asking more of the grid today than we ever have. The grid of the future has to be a hardened grid, but it needs to be a moderate grid, and it needs to be a flexible grid, and it needs to be resilient and reliable.
And, oh, by the way, we need to solve the problems of diversification, decarbonization, digitalization, fix the world, because we're now going to be an electrified world. That's really what we're facing now. There's more change, I think, in the last five years than in the last hundred years. We've gone from a fairly growth-oriented, but static world, to now a rapidly changing one, everywhere.
A lot of great challenges in it. Without going into transmission, pick an area and tell me what you think one of our biggest challenges is for engineers today.

MH Isn't it exciting? I'm hoping we get more engineers coming in because the energy transition is exciting.

We could focus on renewables and transmission, but everybody talks about that. I'm going to talk about distribution.

Distribution gets the last dime and donut. The reason is, if I'm going to invest a dollar, I'll invest it in transmission, because I got one regulator. For distribution I got 50, and it's 150 basis points less than transmission. We need to transform distribution, and regulators in the states really need to make sure that they're funding the distribution. That makes the utilities talk to the regulators and educate and inform them as to what we need to do with respect to distribution. With all this electric vehicle charging, the distribution system is not ready for it now in mass proportion. So we got to transform distribution. I'll probably be the only person talking about that.

AR Well, and it happens to be my love. Distribution is how I was retired as the president of the Electric Power Reliability Alliance. We heavily focused on distribution. And we believe kind of like what you believe. You got 50 regulators, but you also have 50 problems. Everybody doing it a different way. People trying to say, do *my* thing. Technology companies were saying it was proprietary, and it doesn't fit, this my thing doesn't fit with this thing. So we've got a lot of misfit in the distribution systems out there. Now we're trying to bury cables everywhere – nobody wants an overhead cable in their neighborhood, because it'll cause a fire and burn houses down. We've got a lot of things that are going on at the distribution end that we haven't had before, as much as generation is now at the distribution end. I agree with you.

Given that you've just mentioned one of the problems is you've got 50 different regulators

Photo: APC Media

on distribution, but there is not going to be one size *fits all*. If you were talking to a utility as I'm sure you do in your consulting role, but as you talk to them about how do they bring about the best, most reliable, most flexible, how do they build it today for the future, what are the things they should be looking at?

MH From a regulator's perspective, electricity is becoming unaffordable, so affordability is very important. It's the challenge for the engineer, the utility executive, to talk to the regulator about how they can improve distribution in order to save money. I just saw a presentation on distribution automation and you could see the opportunities to save money with respect to making sure that the load duration curves are in the right order. Right now, the load factor on the grid is probably the worst it's ever been, probably around 50%. You could take opportunities to utilize that load factor that's inefficient and spread out the load, and you could do that at the distribution level given you have DERs, distributed energy resources. You plug in your car; you got a battery right there. There are opportunities where the electric utility can inform the utility regulators on how they could save money and keep electricity affordable.

AFFORDABILITY IS VERY IMPORTANT. IT'S THE CHALLENGE FOR THE ENGINEER, THE UTILITY EXECUTIVE, TO TALK TO THE REGULATOR ABOUT HOW THEY CAN IMPROVE DISTRIBUTION IN ORDER TO SAVE MONEY.

AR A lot of the distribution in this country is with the co-ops and municipalities, and there's a different level of regulation even for them. And there's a kind of an insular approach. I know that NRECA is really doing a lot of work to bring in some concepts and ideas that help at the rural level, because the rural electric is no longer rural. I mean, I'm a member of one in Marietta, Georgia. When it was started, it was a small rural thing. Well, it is now one and a half million population. It's right at the city of Atlanta and it involves different complexities than Georgia Power had. Talk about that a little bit at the distribution level, because it's a different level of regulation.

MH I'm an elected official in Ohio. I've been on Westerville Ohio city Council for 30 years.

We're a municipal electric system. And guess what we did on Saturday? We talked about rates and how we can keep rates affordable, not just at the energy level, but at the distribution level. And I know NRECA, the National Rural Electric Cooperative Association and the American Public Power Association, they are great venues to bring in the experts to make sure the membership knows what's going on in the industry. At the municipal electric power level, it's easier than with a regulator. Basically, you have a city council, that's your rate-making body. You don't have to go to a regulator. On the other hand, it could become very politicized.

Here's an example. Energy. Do we go for renewables, or do we go for blocks of energy? We maintained that we are going for blocks of energy, because the cost is the most important.

Those blocks of energy already include renewables and they're growing. We got to be very careful on how we approach not only our energy business or brokering, but also on the distribution automation level. We're introducing distribution automation in our 16,000 meters city and trying to peak shave so that we don't get the capacity charges in the PJM market. And it's nice. It's interesting. You don't have a regulator. You have a legislative body called the City Council. And the electric utility manager could actually drive that experimentation and then keep costs down a lot more effectively than large utilities sometimes. Especially a multi state utility.

AR The headaches that you avoid by being a municipality type, self-regulating, self-rate-setting is amazing.

Let's just say ten years from now, 20% of your former ratepayers, now consumers, become *prosumers*. That's going to change a lot of what you have to do, because now as a prosumer, they want to sell you power only when they want to sell it to you. And then they're going to buy power when they need it. How are you handling that approach? Or are you even thinking about that approach? Westerville is a very forward-thinking community right outside of Columbus, and it's going to happen there. You're going to get a bunch of EV adoption. You're going to have solar panels on the roof and some guy will put a wind farm in his backyard.

How are you going to handle your rate payers moving to prosumers?

MH That's a great question, because do we handle it as an aggregate of 16,000 meters or do we handle it at the meter level? And right now, it's a hybrid. We try to avoid the capacity charges by peak shavings. We provide opportunities, such as the nest thermostat going into the thermostats and reducing the load, also providing subsidies if a commercial building changes out their LEDs or changes out their lighting for HVAC, but also puts in solar panels. If they provide us the opportunity, us being the municipal electric system, to actually gate their load on their demand, you can see how we could peak shave in that environment.

Michael being sworn in for the city council, 1993

WE TRY TO AVOID THE CAPACITY CHARGES BY PEAK SHAVINGS. IF THEY (THE CUSTOMERS) PROVIDE US THE OPPORTUNITY, US BEING THE MUNICIPAL ELECTRIC SYSTEM, TO ACTUALLY GATE THEIR LOAD ON THEIR DEMAND, YOU CAN SEE HOW WE COULD PEAK SHAVE IN THAT ENVIRONMENT.

Michael being sworn in for the city council, 2021

The same goes for EV charging. It if we are allowed to get to the EV charger and say *not now, or now is a good time to do it*. So it is going to be at the device level. The issue is going to be: when they become prosumers, how do we interact with their actions? I think we're at the leading edge and it's really not a big leap to go from proactive at the aggregate level and then reactive at the prosumer level. I don't think it's a leap for us.

AR That's good. Excellent. Last question I've got for you:

CIGRE. What's the value of CIGRE to you personally and what was the value in your career?

MH CIGRE is a lot like sitting at a table filled with experts. And the United States is not the only expert country in the world. So you find out what they're doing. Thailand rebuilt their transmission grid, for example. What is the UK doing with respect to charging? How about Italy? What's Greece doing? You're sitting at the table with experts beginning to talk and trade information. And that knowledge exchange is really what CIGRE is all about.

The tagline is for power system expertise. But imagine you're sitting at the table with experts from around the world in any space that you're in. From a career perspective, if you're in transmission or distribution and you want to know what's going on in the UK or in Italy or in Australia, you likely know somebody that you could talk to. You also know the information through E-CIGRE, our searchable site, to go to technical brochures to figure out what's distribution automation like in Melbourne, in Australia, for example. It's a knowledge exchange and it's also a career development perspective. Now, I've been fortunate that I was the U.S. National Committee president from 2010 to 2016. I'm now the CIGRE VP Finance and Treasurer in Paris. I don't reside in Paris.

We got through COVID and we're doing quite well with respect to our marketing and branding campaign. We just got approved a strategic plan to grow our membership and to evolve our technical base to deal with the energy transition.

AR You talked about marketing and growing the membership. There was a sense, I don't think it's true, but there was a sense that IEEE and CIGRE are kind of moving to different parts of the world trying to become the more dominant event. But in truth, they play different roles.

CIGRE IS A LOT LIKE SITTING AT A TABLE FILLED WITH EXPERTS. AND THE UNITED STATES IS NOT THE ONLY EXPERT COUNTRY IN THE WORLD.

MH CIGRE was born in 1921 out of the IEC, which was a standards body, and CIGRE became a technical collaboration to help develop standards for the IEC. IEEE is a standards body. IEEE is worldwide. CIGRE is worldwide. I see them as complementary, and I don't like to call them competitors. I really like to see them as complimentary. IEEE does have an academic side in their standards development as well as the industry side. CIGRE tends to be more on the industry side with policymakers and decision makers at that technical level. I see them as handing glove.

CIGRE IS A KNOWLEDGE EXCHANGE AND IT'S ALSO A CAREER DEVELOPMENT PERSPECTIVE.

AR I think there's a memorandum of understanding that has just been signed between the two organizations, because standards, and that's CIGRE to me, is knowledge of practical application. These are the people that actually put the power into the homes and into the factories and make the world run. It's a good collaboration.

MH Two heads are better than one.

AR Much better.

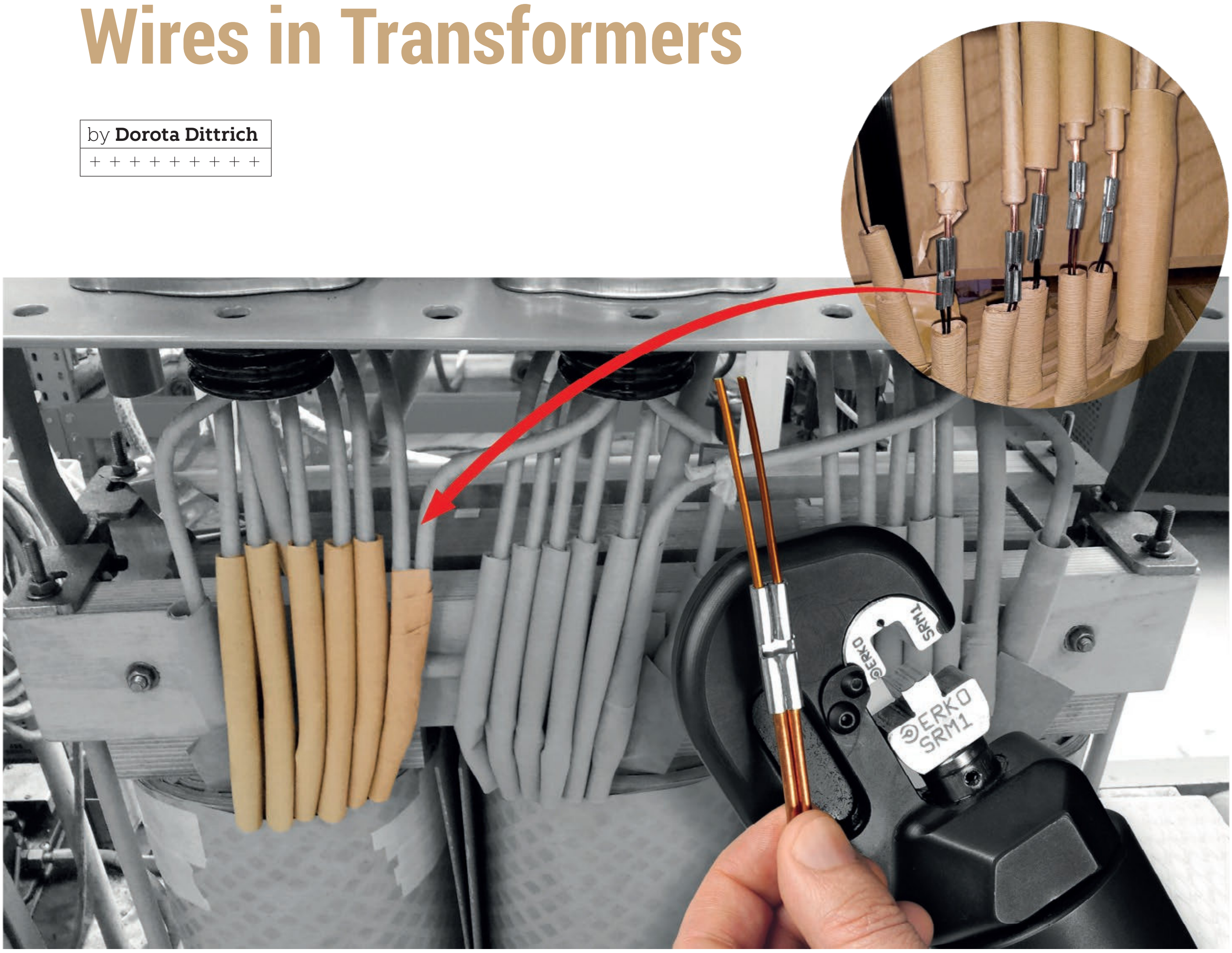
MH If I'm looking at distribution automation, I got IEEE, I got CIGRE and I got a lot of opportunity not only at career development, but also in technology *en mass*.

AR I appreciate you doing this. Thank you for doing the interview.

Photo: APC Media, Michael Heyeck

Innovation on a Global Scale: Technology for Connecting Aluminium and Copper Enamelled Wires in Transformers

by **Dorota Dittrich**



Without transformers, the distance between power plants and all kinds of their recipients would have to be much larger. No wonder there is a constant strive to improve transformers' efficiency and to facilitate their usage.

If it was not for transformers, the electricity distribution would not be as efficient as it appears to be today. There is a reason for calling them the heart of a power system. Without transformers, the distance between power plants and all kinds of their recipients would have to be much larger. No wonder there is a constant strive to improve transformers' efficiency and to facilitate their usage.

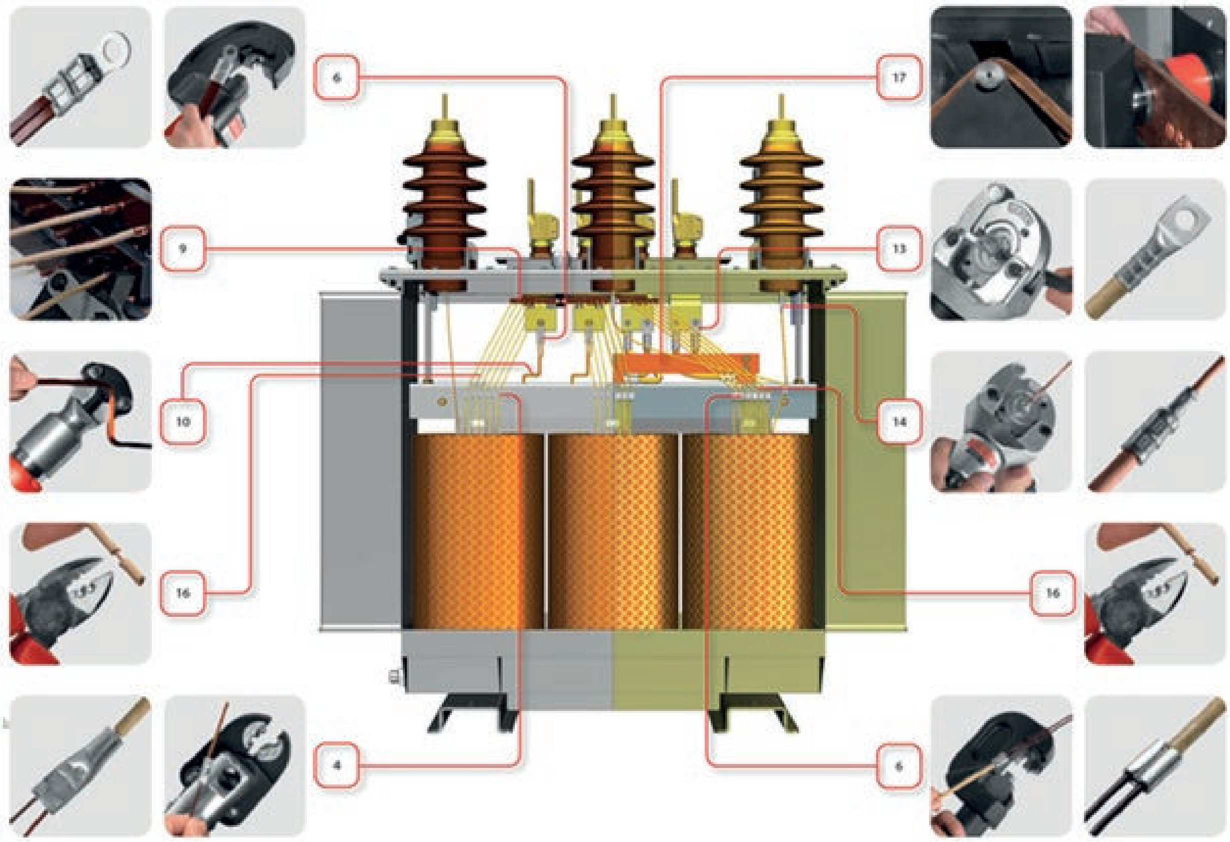
In response to the constantly growing needs of the modern market, an innovative connection system for aluminium and copper wires in transformers has been designed.

The technology is dedicated to connecting both round and profile enamelled copper and aluminium winding wires in motors and oil transformers. The designed connectors and terminals are applicable in all branches of the economy, in which enamelled wires are used - e.g., in industrial power engineering, electric motors, automotive industry, railway industry and shipbuilding.

A wide range of available types of connectors allows to connect any cable within the scope of the technology connectors' application. All enamelled copper or aluminium, profile or round wires can be connected.

Photo: ERKO

Examples of places of application of the connectors in a transformer



A single connector enables connecting wires of different cross-sections, shapes, and materials. A wide range of available types of connectors allows to connect any cable within the scope of the technology connectors' application. All enamelled copper or aluminium, profile or round wires can be connected. With observance of the relevant rules, the connectors can be also applied for connecting single-strand and multi-strand wires without insulation.

Technology innovation

Thanks to this technology, the process of removing enamel insulation from the wires has been eliminated as the connectors break through the enamel and into the core of the connected wires. That enables obtaining a permanent electrical and mechanical connection. The gradation of the teeth placed on the surface of the connector ensures lack of weakening of the core of the cable. As a result, the created connection is protected against oxidation, breakage and formation of notches, which guarantees its trouble-free working time for years.

Thanks to this technology, the process of removing enamel insulation from the wires has been eliminated as the connectors break through the enamel and into the core of the connected wires. That enables obtaining a permanent electrical and mechanical connection. The gradation of the teeth placed on the surface of the connector ensures lack of weakening of the core of the cable.

In the process of stripping wires using traditional technology, the wire is narrowed (a notch is formed), which leads to a local reduction in cross-section and mechanical weakening of the wire. The use of the innovative technology eliminates this problem and guarantees longer trouble-free operating time of cables and devices, in which modern connectors and terminals have been installed. The elimination of preparatory processes provides a significant competitive advantage for this technology over traditional methods of making connections on enamelled wires.

Dorota Dittrich works as a Junior Marketing Specialist for ERKO, one of the electrotechnical industry key suppliers. She graduated in linguistics in business and received her Master of Arts from The University of Warmia and Mazury in Olsztyn, Poland. She can be reached at dorota.dittrich@erko.pl

An alternative to removing enamel from the wires

The process of connecting enamelled wires using the traditional connection technology requires the usage of mechanical or chemical methods of removing the insulation from the wires. Mechanical methods include scraping the insulation, which causes dust and pollution of the working environment. Another method is burning or soldering the insulation with hard solder with the addition of silver. However, those activities pollute the environment with toxic results of the process and require the installer to have special qualifications.

The chemical method is based on dissolving the insulation in corrosive substances. Both methods are burdened with many technological and environmental flaws. Thus, to increase efficiency and durability of the connections, using this new method, the process of removing enamel from the wires has been completely eliminated.

The disadvantages of soldering and preparing the wires using the mechanical method

Stripping the wires mechanically is associated with problems with the precise removal of the insulation from profile wires. It also causes local narrowing of wires, which contributes to their electrical and mechanical weakening (especially in case of aluminium wires).

Additionally, both mechanical methods and soldering generate solid impurities (fillings, charred insulation) that get into the transformer, causing a potential source of short-circuit. What is more, in case of mechanical technology, typical dies do not always match the size of the crimped wires, which leads to the formation of flashes (sharp edges). Working with maladjusted dies makes it necessary to supplement the missing cross-section with fillings. Soldering, on the other hand, requires preliminary preparation of the surface of the wires and using expensive solder and suitable equipment. It also often damages the insulation of the wires polluting the environment with gases generated during this process.

Special features of the innovative technology

The innovative system enables making durable connections of the highest quality, that work in transformers trouble-free for many years. The technology itself is clean and prevents contamination of transformer windings. Elimination of harmful processes of soldering and burning the insulation results in reduced pollution of the working environment.

The system guarantees increased efficiency in comparison to the technology previously used. As it is dedicated to transformer producers, the elimination of preparatory processes (including the energy consuming soldering process) ensures that the system is economical. Universal technology enables connecting wires of different cross-sections, shapes and materials with a single connector, which leads to the possibility of reducing the stocked assortment of connectors in general.

Research and tests

Constant research is conducted to evaluate the effectiveness of the mentioned connectors and dedicated tools. To carry out the research, the so-called test chain is performed. It is created by making serial connections of equal conductor sections with the use of tested connectors. The lengths of the cable sections connecting individual connectors are strictly defined in the PN-EN 61238-1:2004 standard. During the research, the changes in connection resistance between heating cycles are registered and the temperature of all connectors and its changes in all stages and cycles is measured. In addition, the process of cyclical heating of connections made with innovative connectors is conducted. It is carried out in accordance with the requirements of the standard.

Soldering with tin solder

Hard Soldering

Mechanical Crimping

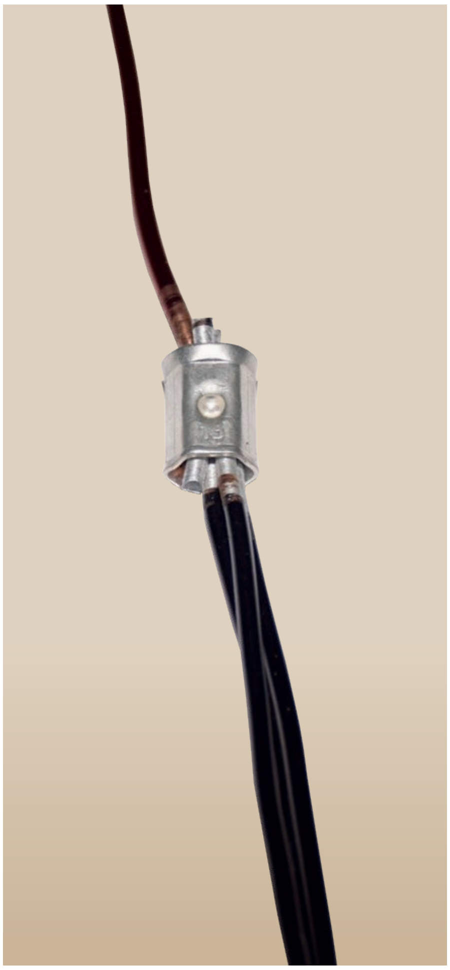
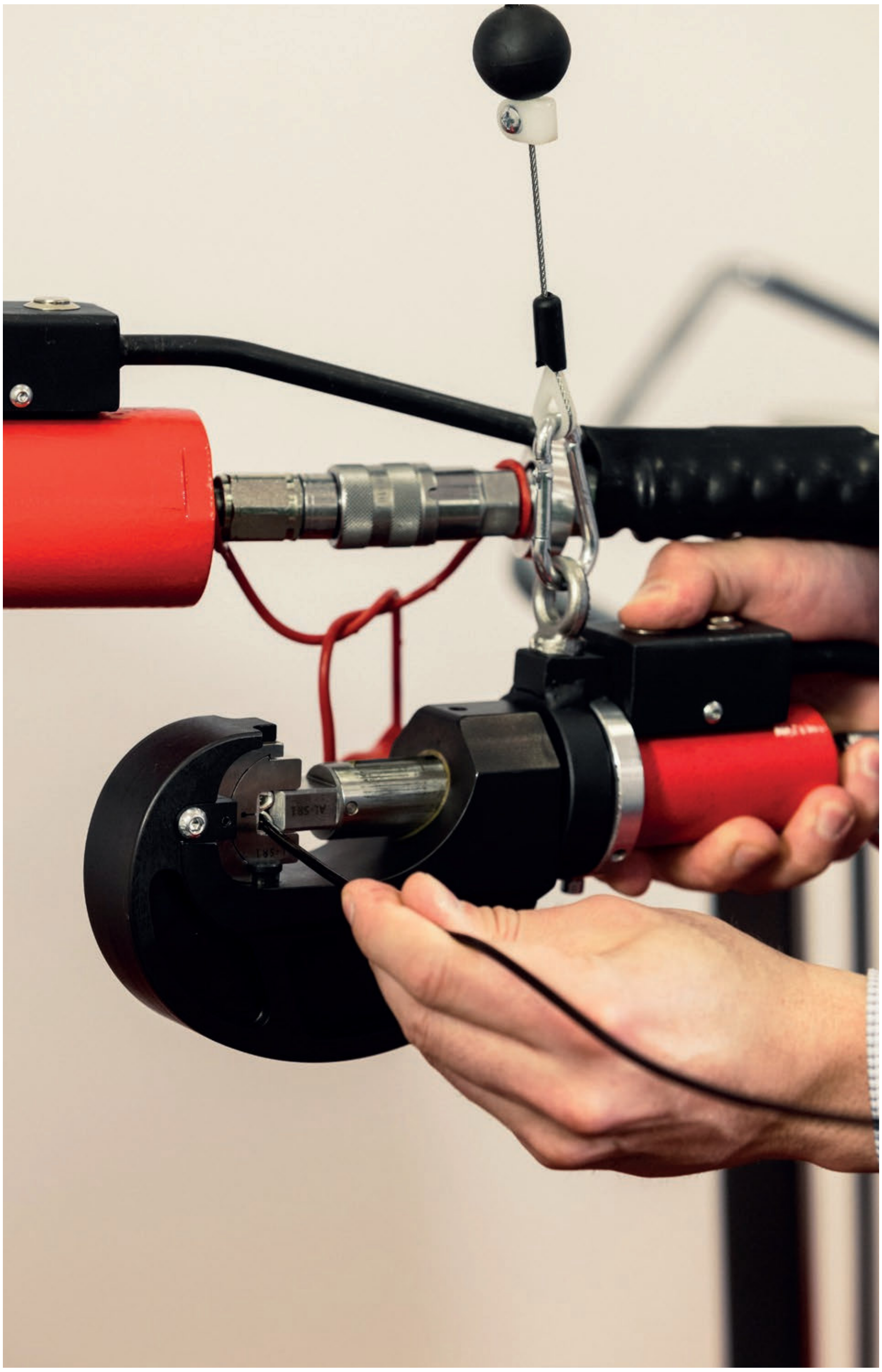


Photo: ERKO

Research and tests



Technology that enables connecting wires in enamelled insulation without the need of taking the enamel off is an innovation on a global scale – at this point it is not even the future, but the present of power transformers.

The measurements of the mechanical properties of connections are also constantly carried out.

The tested connectors cannot introduce additional resistance to the test circuit, and their temperature in process of cyclical heating cannot exceed the temperature of the conductor on which they are installed.

Technology that enables connecting wires in enamelled insulation without the need of taking the enamel off is an innovation on a global scale – at this point it is not even the future, but the present of power transformers.

Evolving Landscape of Power Systems in the EU and Beyond

Written by **Saifa Khalid**

Photo: Shutterstock, PTR Inc.

Saifa Khalid is a senior analyst at PTR Inc. Her main area of interest is power systems. Currently, she leads the power grid research team in developing PTR's syndicated power grid services and manages custom research projects for Fortune 500 clients globally. The topics under her mandate include HV switchgear, MV switchgear, power transformers, distribution transformers, substation automation, power factor correction, etc. Saifa comes from a technical background and has a BSc. degree in Electrical Engineering.

The landscape of power systems across the globe is undergoing a significant change that is more pronounced in advanced economies than in developing economies. Compared to developing economies, advanced economies have the required fiscal space to invest in renewable generation and electric vehicles, followed by the mandatory upgradation and expansion of electricity grid infrastructure.

The shift is primarily driven by climate change as increasingly frequent and severe weather events, from hurricanes to wildfires, pose substantial challenges to the reliability and stability of power systems worldwide. Weather extremities can potentially damage grid infrastructure and disrupt the supply chain of fuel (for conventional generation) and power grid equipment, in turn leading to power outages affecting millions of consumers. The vulnerability of electricity grid infrastructure to climate change requires power system planners to reassess their entire strategy.

The major challenge for the electricity grid operator is the inherent vulnerability of conventional power sources, including fossil fuels and nuclear power plants, to climate-related disruptions. Furthermore, the widespread integration of renewable energy with the electricity grid and the adoption of EVs has introduced another layer of complexity in grid management.

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The European Union has also taken measures to phase out fluorinated gases and ozone-depleting substances that will not only help mitigate the impact of climate change in the long run but also shape the future of power systems within the EU.

Photo: Shutterstock

The landscape of power systems is rapidly evolving in the advanced economies, specifically in the EU member states, but as alternative technologies become available and their prices drop, stringent regulations are likely to be introduced in developing economies as well.

There is an urgent need to move towards resilient and adaptive power systems that can navigate these challenges, unlike traditional power systems, which are at greater risk. This requires reinforcing the physical electricity grid infrastructure against climate-related disruptions and deploying advanced technologies, especially artificial intelligence-based solutions, that increase the grid's resilience.

The European Union has also taken measures to phase out fluorinated gases and ozone-depleting substances that will not only help mitigate the impact of climate change in the long run but also shape the future of power systems within the EU.

This move has pushed the original equipment manufacturers of power grid equipment to adopt sustainable practices and move towards utilizing environmentally friendly substances during the manufacturing process. The phased elimination of gases with a significant global warming potential aligns with the broader efforts to move towards cleaner and sustainable energy solutions. The regulations are being enforced at voltage levels where the alternative technology is available, but it is expected to either allow conventional technology or revise the deadlines in case the alternative is unavailable. This has also created room for innovation in the power grid equipment industry, leading to the invention of environment-friendly gas mixtures that can be deployed in the switchgear for a certain voltage level while research is being conducted for gas mixtures that can be used in switchgear operating at higher voltages.

The regulations are crucial in steering the industry toward an environment-friendly and sustainable future. However, the entire transition will be subject to compliance and commercial availability of alternative technologies. The landscape of power systems is rapidly evolving in the advanced economies, specifically in the EU member states, but as alternative technologies become available and their prices drop, stringent regulations are likely to be introduced in developing economies as well.

Bala Vinayagam

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The idea was to create an infrastructure for them that is sustainable and that keeps the power on for these remote communities, and especially the underserved communities.

Interview with **Bala Vinayagam**

Vice President of the Microgrid Program
at Schneider Electric

Photo: GettyImages

Alan Ross: Hi, I'm Alan Ross. I'm the Managing Editor of APC Media, our APC Technology Productions, Transformer Technology, Power Systems Technology. We are here at the RE+ 2023 event in Las Vegas.

My next guest is Bala Vinayagam. He is the Vice President of the microgrid program for Schneider Electric.

You've been around this space from the utility perspective. You've got a PhD. What's your PhD in?

Bala Vinayagam: It's in electrical and computer engineering, primarily focused on long-term stability of the bulk power systems.

AR Oh, wow. I love that. Okay, so you're the guy. Let's talk about what you've seen in the industry, not just focused on the grid part of it. We're here and it seems like we're at an inflection point, that we've crossed the Rubicon, where now we've got people saying, *Hey, this will really work*. We've got wind and solar and storage at scale. Now we're starting to talk about microgrids and how microgrids can come in, from a resiliency standpoint, from a utility standpoint, and more. Talk about where we are in terms of microgrids from the beginning to where we are today.

BV I started my microgrid journey back in 2007 when I was working for General Electric. At the time, it was more of community microgrid. These are remote communities in which you are moving diesel by truck, pretty expensive. It's cold communities back in Canada. How do you really create power in those communities that will make them more self-reliant and reduce their dependency on diesel? That's how the first journey for me and microgrids started. At the time we started with hydrogen, there was hydrogen, a small wind farm, then you have diesel, where you can't run the wires to these remote communities. There are 2,000 people, for example in the Rockies. How do you really get these communities powered up? That's where the journey started for me first.

AR Was it not also all those communities starting to be self-reliant, but they had the grid backing them up? They were always there. The grid had to be there when needed.

BV Most of the time, it's very difficult to run the wires to these last miles from the grid perspective. They're probably potentially on the diesel for quite some time. It's very expensive. One, you need to keep them powered on for all the safety-related purposes. Two, the community has been in the middle of the transition to green infrastructure, so they may not want to run on diesel. The idea was to create an infrastructure for them that is sustainable and that keeps the power on for these remote communities, and especially the underserved communities.

AR Now, microgrids have evolved. What was the next step from those small microgrids, for example a community, a college, a residential even sometimes, they moved and they started to change in application. What was the next leap?

BV Before I explain what this evolution is, I think we need to take a step back and really look at the traditional bulk power system. For a very long time, we had a deregulated generation environment, a bulk transmission system, and a radial distribution system in which the loads are always planned and the generations are always dispatchable. Now, we all know that this is heavily dependent on the fossil fuels. So as the industry wants to deeply decarbonize its infrastructure, then you're going to bring in more solar, more wind. They both are not dispatchable. Now, your loads are changing. You are electrifying the buildings. You have fleet electrification, which means that loads are getting smaller with EVs. Your loads can no longer be planned. Your generation is no longer dispatchable. How do you manage this complexity that's going to come in as we continue to deeply decarbonize?

***IF WE TRULY WANT TO TRANSFORM THE GRID IN THE FUTURE**, WHICH WILL HAVE A CO-EXISTENCE OF BOTH THIS DECARBONIZED, CENTRALIZED GENERATION TRANSMISSION, IT ALSO NEEDS TO CO-EXIST WITH A TRULY DECENTRALIZED, HEAVILY DISTRIBUTED AND HIGHLY DEMOCRATIZED DISTRIBUTION AT WORK THAT NEEDS TO HELP BRING THE STABILITY THAT IS REQUIRED IN THE GRID.*

AR Oh, I like that. You set the stage for where you're going with these microgrids. But actually, that's the problem of the whole DER revolution.

BV Correct. If we truly want to transform the grid in the future, which will have a co-existence of both this decarbonized, centralized generation transmission, it also needs to co-exist with a truly decentralized, heavily distributed and highly democratized distribution at work that needs to help bring the stability that is required in the grid. This is where multiple different tools need to come together from our toolkits to make that grid stability because base load generation will no longer exist.

What happens when the sun goes down and the wind goes down? Something needs to come up. We need a lot of different things. Okay, how do you now look at demand response programs? How do you look at demand-side flexibilities? The microgrid brings in a variety of different outcomes that's almost like a Swiss Army knife. A lot of weather events are happening. No matter how much you harden the grid, you can't harden it against a weather-related event. I need to have a resilient backup of the power, number one. Two, the cost of energy is going to keep going up.

As you continue to decarbonize the grid, and even if the cost is going to be low, I think there is an element of the transmission and the delivery charges that is going to come and sit in terms of increased electricity cost for all of us, which means that we need to take control of that. I'll give you an example of why I'm a very strong advocate for it from my personal story perspective. The third one, when you build these outcomes of reducing the cost, bringing the resilience, you need an infrastructure that needs to be decarbonized. That's where microgrids come into play. While they allow the decentralized distributed network to produce, consume this power at the cheapest cost with proper backup and as a green infrastructure, they also provide the flexibility that will allow the grid to remain more stable when the sun goes down and the wind goes down.

I THINK HAVING STORAGE AS A PART OF THE SOLAR INFRASTRUCTURE, *THE WIND INFRASTRUCTURE, HELPS US TO ADDRESS A VARIETY OF NEEDS THAT POTENTIALLY NEED NOT BE ADDRESSED BY BRINGING IN PEAKER PLANTS.*

AR Where does storage fit in all of this?

BV In my opinion, storage is the most important enabler of what this is going to look like. Simple example, you can have solar. Now, we are all very familiar with this. No more is it a duck curve. It's more like a valley, actually. The head of the duck is probably becoming much longer, or probably even steeper now. Thinking about that, with the NEM 3.0, the new regulation that's coming in from curtailing this excess solar when the price goes negative, what are you going to do with all these green electrons now? These green electrons need to be stored, why should it go to waste? This is when the storage comes into play. I think having storage as a part of the solar infrastructure, the wind infrastructure, helps us to address a variety of needs that potentially need not be addressed by bringing in peaker plants that someone like Ercat is paying at $5,500 per megawatt hour. You can bring this cost down considerably by having storage as a part of the portfolio.

AR Some of the storage things we've seen here, upstairs at this event, the flow battery storage, the utility scale storage, they are really happening faster and faster. There's a company that uses vanadium. That's a very plentiful resource. It's like copper. There are solutions that are coming on at scale which allows wind and solar at scale to be able to support the grid. Smart grids for industrial, commercial, talk a little bit about where they play, because the industrial commercial people that we talk to are afraid that they'll be left behind. Everybody's worried about Mrs. Jones getting her power and the guy getting his solar in his car and et cetera. And you're saying, *Look, we are the backbone of America, the industrial, the petrochemical industry, everything.* We got to make sure we get smart power and good power and quality power. You're seeing the move to microgrids in that area. Are you seeing that?

BV I do, actually. I see the commercial industrial in multiple folds. I see them as part of the retail, real estate, logistics as one area, office buildings included in that. How do you now look at this commercial infrastructure and how do we move this commercial infrastructure from being these buildings on concrete, or the loads on concrete, to generation on concrete? What can we do to make that happen? That's one.

Then two, I see the light industrial customers and the heavy industrial customers, now they need to move this energy and take control of it. These PPAs that are going to come in place are probably going to increase in cost because of utilities. They need to maintain the cost of the electricity at a lower level while making sure that the electrons they're buying are green.

This is where I think the microgrid will come in and help them in terms of ensuring that, one, they take care of their Scope 1, Scope 2 emissions. Plus, whatever product that they are making, it is a Scope 3 for someone else. This is an exciting time for these guys.

One, I want to take control of my destiny in terms of the power that I am going to produce, consume. Two, making sure that I don't miss out on the regulatory environment when it comes to this compliance declaration. Now, I think it was yesterday, there was a regulation that was passed by California that every corporate company needs to declare their Scope 1, Scope 2, Scope 3 emissions. What's the best way for these companies to now address that part is exactly that. Whether you are a smaller player or a bigger player, you need to take control of your electrical infrastructure needs, your electrification needs, which comes with a lot more of self-reliance if you are producing and consuming that power, at the same time even participating in the grid to sell that power.

***WHETHER YOU ARE A SMALLER PLAYER OR A BIGGER PLAYER**, YOU NEED TO TAKE CONTROL OF YOUR ELECTRICAL INFRASTRUCTURE NEEDS, YOUR ELECTRIFICATION NEEDS, WHICH COMES WITH A LOT MORE OF SELF-RELIANCE IF YOU ARE PRODUCING AND CONSUMING THAT POWER, AT THE SAME TIME EVEN PARTICIPATING IN THE GRID TO SELL THAT POWER.*

AR It's brilliant. Everything's changing and it's all changing for the good. Last but not least, Schneider Electric. What is it that you bring into the microgrid world?

BV Again, Schneider is very heavily focused on enabling two things. One, digitizing customers' infrastructure. You got to first digitize this infrastructure for them to understand where their needs are. We are heavily entrenched in helping the customers digitize their infrastructure, help them become more self-aware, or create the situational awareness of their infrastructure's Scope 1, Scope 2, Scope 3 emissions. Two, we help customers build their infrastructure that allows them to produce, consume, and export power. We help customers in terms of their energy management needs. We

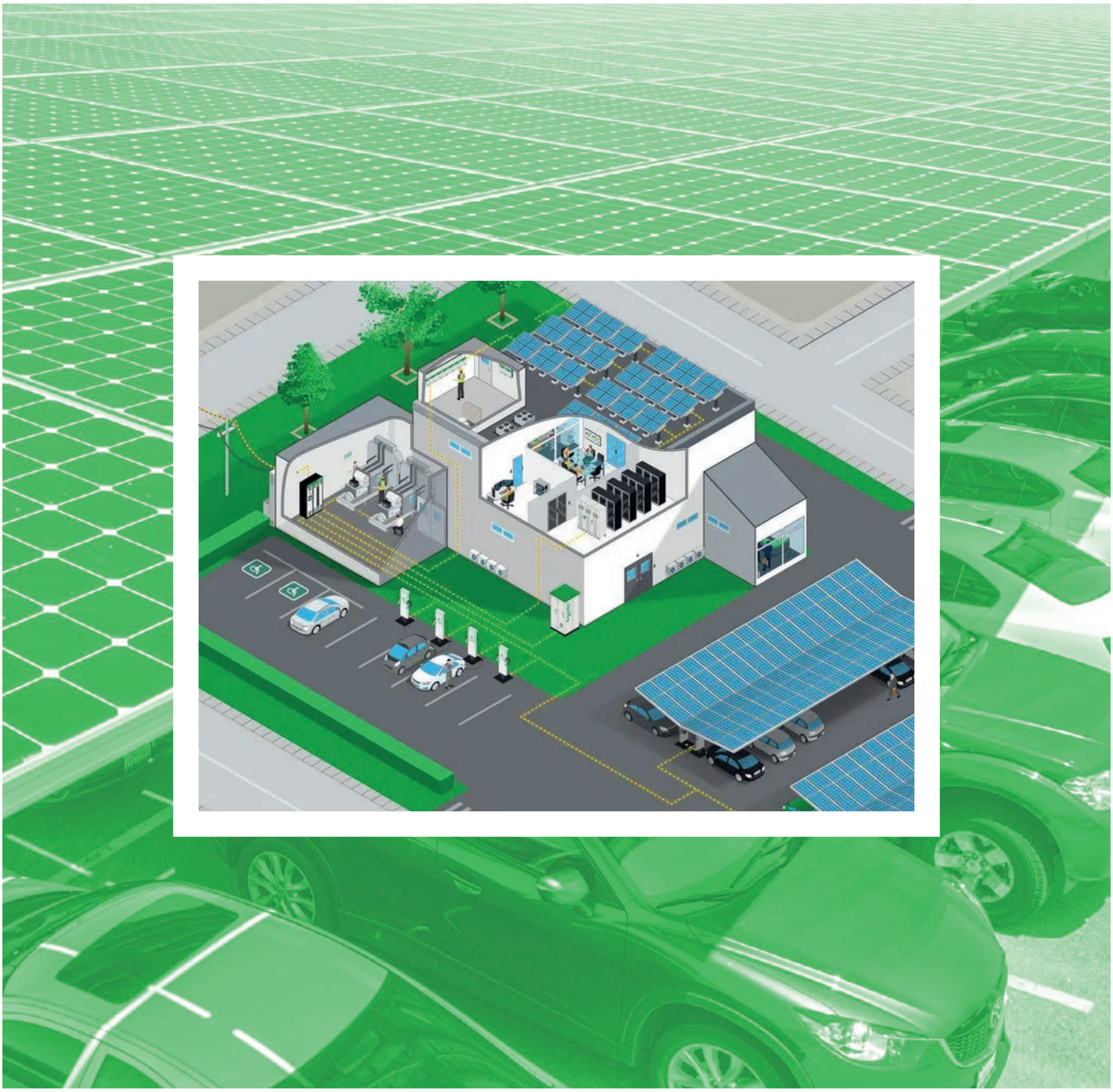


Photo: Schneider Electric

help them modernize their electrical distribution infrastructure. We help them modernize the bridge between the IoT, the OT, and the IT structure. We help these customers to connect them to the enterprise network. Thereby this decentralization and the democratization of the

infrastructure can happen, and the electrification of the buildings and the electrification of the fleets becomes a reality.

AR Excellent, Bala, thank you so much for sharing with us this.

BV Thank you for having me.

Photo: GettyImages

INTERVIEW WITH DEEDEE SMITH

eMobility Marketing Manager and eMotors Global Lead, Solvay Materials

WPS: Thank you, DeeDee, for joining us for this interview today. It's really a pleasure to have you and to hear your thoughts and to share your experience with our readers.
We got in contact with you through our contacts from the CWIEME event that we both visited this May. So can you tell us a little bit about how your collaboration with CWIEME started?

DeeDee Smith: The first time that we attended the CWIEME show was two years ago, and we found it by looking for trade shows for coil winding. Solvay had never attended the show before, so it was our first experience. I started interacting with the organizers asking about the ability to talk about some of our products. We had such an awesome first year and they were extremely helpful, everything from getting the booth ready to helping us prepare for the talk that we were giving and then coming by and checking on us making sure that the show was going well and that we were getting what we wanted out of it. I would have to say that that first show really opened our eyes to how large CWIEME is and that it really encompasses the entire supply chain around coil winding.
This year I've been a bit more involved with the group. I participated in the education panel, which was, I think, the first one that they have ever had. That was a different experience, not just interacting with customers, but now also interacting with students and really understanding what is driving them, so we can tap into that next generation talent pool.

You are currently working as an e-mobility Marketing Manager at Solvay Materials, but you also have a background in chemistry. Can you please tell us how did your unique expertise contribute to your success in the field of e-mobility? Because this is not really the typical way.

I have a PhD in organic chemistry from Northwestern University in Chicago, IL. And there I was doing something completely different. I was studying copolymers for drug delivery. It was very-interdisiplinary work. I worked with the Children's Hospital downtown. I would synthesize drug-containing monomers, polymerize them and make the copolymers, and then the nanoparticles. Then I would give them to my collaborators for testing. I found I was really good at crossing these science boundaries, being able to communicate what I was doing from a chemistry standpoint to doctors and clinicians, and then also taking their work to conferences and being able to explain to other chemists the impact of the chemistry that I was doing in these lab settings. I found that having that ability to talk, cross science talk, was really beneficial. It was also beneficial when I did my post-doctorate and I was writing grants and trying to get funding, being able to lay out that story in a way that anybody could understand it, regardless of what their background was.
After my postdoc, I decided that I really wanted to get into industry and see the impacts of what I was doing on a day to day basis in the market. Therefore, I joined Solvay in 2011. I joined one of their advanced engineering, advanced chemistry groups. We were looking at technologies that weren't to be developed for another 15 to 20 years. After a couple of years of doing that, I felt like I wasn't really close enough to the customer or the business. I wanted to understand how we were making money and what was really driving our business and our customers. I moved into a more business facing group doing product development. I was still in R&D, but in a position that allowed me to interface more with our customers. I started traveling with our front line folks, going directly to customers and talking with them and using that background of explaining things in a way that everybody can understand to explain to our customer how our products really worked and what we were doing chemically to make them work in their applications.
After a couple of years, I decided to make a very large leap and leave R&D and go to the commercial side of our business. I started in sales development where I was actually owning customer accounts and driving business development at those customers before moving into this market managing position. But I would say that the skills that I developed early on, being able to talk to people regardless of what their background was and explain complex concepts, has made me successful in this job. Those early lessons in communication skills and talking across disiplines to eexplain things in a way that they understand has been beneficial.

Photo: CWIEME

> This transition has brought about a wave of new e-motor innovations. You have a lot of brilliant people in this industry that are coming up with incredible new designs, and those new designs are really pushing the performance boundaries of incumbent materials.

You said that you were developing solutions that were really advanced, really far in the future. And what's a really big topic currently with the development of technology is sustainability. As the transition to e-mobility is actually a pivotal moment in the automotive industry, how do you envision the future of e-mobility and what role does Solvay play in shaping this future through the e-motor solutions?

I would say that this is a super exciting time, being able to be in the position that I'm in today, in this moment where you're seeing this mass transition to e-mobility, I feel very fortunate. For me, this transition has brought about a wave of new e-motor innovations. You have a lot of brilliant people in this industry that are coming up with incredible new designs, and those new designs are really pushing the performance boundaries of incumbent materials. And so I see our role as making the impossible possible, opening up the design space for engineers, allowing them to have materials that are going to help them enable cleaner, safer and more energy efficient mobility.

"Incorporating sustainability is something that is a core value at Solvay. It's in everything that we do, it's not an afterthought. When we're in there talking to engineers about the products that are going to provide value in their applications, we're also talking with them at the same time about the sustainability profile of that product."

You actually answered two of my questions, because my next one was the one regarding the approaches driving the adoption of sustainable and efficient technologies in electric vehicle industry. Do you have anything to add to this?

One of the things that makes Specialty Polymers really great is that we have one of the broadest portfolios of highly engineered thermoplastics in the industry. That comes with some great pros, but it also comes with some cons. One of the advantages is that we have the ability to pick the right material for the right application. Materials that are going to balance performance and economics. But when you look at our portfolio and you see thousands of grades of material, it can be very overwhelming to know where to even start to select the right material. A few years ago, our marketing decided that we were going to shift from being product-focused to being market-focused, and more specifically for automotive, systems-focused. We wanted to understand the systems and the value our materials can bring to those systems. For eMotors specifically, that meant working with our internal experts to identify solutions for applications where we thought we could add value. But you have to prove that value to your customer and speak their language.

Read the full article in the **latest issue** of Women in Power Systems.

Photo: CWIEME

Bridging the Gap:
Understanding Externally Gapped Line Arresters (EGLA) Technology Through the Lens of RTE France

by **Luis Diaz**
and **Florent Giraudet**

Although the [EGLA] technology has undergone significant improvements and widespread development globally, its full benefits are still underappreciated.

Luis Diaz is an R&D Engineer at the National Center of Expertise for the French Transmission System Operator (TSO), RTE. He holds an MSc Degree in Electrical Engineering from the Simon Bolivar University in Caracas, Venezuela, and a PhD through a CIFRE program in collaboration with EDF R&D and the University of Limoges, France. His expertise lies in Lightning Protection and Insulation Coordination of Power Systems, encompassing both underground and overhead systems. At RTE, Luis is entrusted with drafting technical specifications for composite insulators and overhead line (OHL) surge arresters. He offers expert guidance to both the engineering and maintenance divisions, tackling intricate challenges in lightning protection systems and insulation coordination. Furthermore, he spearheads modifications to the national maintenance policy, aiming to diminish electrical risks to third parties. Luis represents RTE and France in the B2 and C4 CIGRE committees, as well as in the TC36 and TC37 IEC Committees.

Florent Giraudet received a Dipl. Ing. Degree in Industrial and Electrical Engineering from CESI in Lyon, France in 2010. He later joined Siemens, Germany as Area Sales Manager for surge arresters application. He then took on additional responsibilities in the business development of overhead line solutions that include applications of transmission line arresters as well as polymeric insulators. He subsequently took over Sales & Marketing responsibilities at Tridelta Meidensha. Currently, he offers consulting for lightning performance and surge arrester technologies.

Photo: Huaming

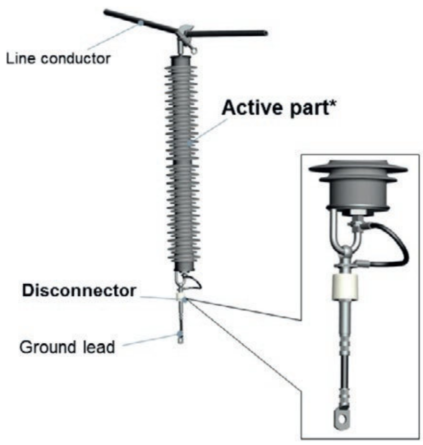
Externally Gapped Line Arresters (EGLA) are a solid-state technology comprising Metal Oxide Varistors (MOVs) to prevent lightning-induced outages on overhead lines. The high-voltage network industry in Japan pioneered the development of the first EGLA 40 years ago to address the unique needs of overhead lines. This was achieved by merging the distinct characteristics of MOVs with the advantages of air gaps. As early as 30 years ago, Japan had already installed more than 30,000 EGLA units in their network.

Although the technology has undergone significant improvements and widespread development globally, its full benefits are still underappreciated. MOV-based gapless surge arresters are internationally standardized for the protection of critical equipment, such as power transformers. However, their application in lines remains a subject of considerable debate. While some have mastered this technology, others are only beginning to explore its potential. Some uses, as we will see, go beyond protection against lightning but allow for ensuring optimal levels of safety with respect to people and equipment.

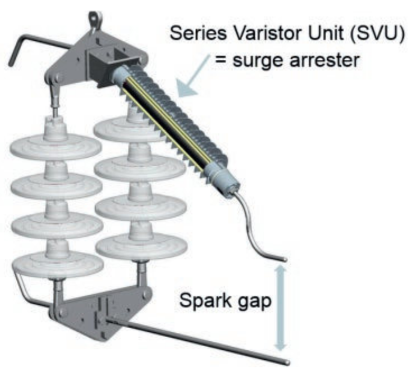
French TSO, Réseau de Transport d'Électricité (RTE), is contributing valuable insights to help us understand how EGLAs can address some of the most urgent challenges facing today's power grids, particularly in terms of safety and protection against lightning-induced network outages. Guided by RTE's unique expertise, this article aims to demystify EGLA technology, making it more accessible and comprehensible to a wide audience. By sharing extensive experience from RTE, the article illuminates the technical intricacies, safety protocols, and operational efficiencies of EGLAs. It targets a diverse readership, ranging from industry experts to policymakers, aiming to educate them on EGLA's untapped potential for enhancing grid reliability and safety. Discover why this technology could be the next significant advancement in high-voltage applications worldwide.

By employing EGLA, the follow current is interrupted post the drainage of the lightning impulse to the ground.

As a result, there is an effective elimination of the 50Hz current flowing into the ground, preventing any rise in 50Hz ground potential.



NGLA - Directly connected to power line



EGLA (1 SVU) - Isolated from power line through a series gap

When did RTE first start using EGLA in its high voltage applications, and what was the main driving factor that motivated this adoption?

Toward the close of the 1990s, former TSO EDF (Électricité de France) had incorporated EGLA into all three phases of specific non-shielded towers. A primary concern at the time revolved around the flow of 50Hz fault currents into the earth following lightning flashovers. This becomes particularly problematic when towers are situated close to sensitive structures such as homes, schools, workshops, and markets. The flow of fault current into the ground results in a noticeable increase in the electrical potential of the surrounding soil. This poses risks to both electrical equipment grounded some distance from the tower and individuals either in contact with a grounded structure or moving in the tower's vicinity due to touch and step potentials. By employing EGLA, the follow current is interrupted post the drainage of the lightning impulse to the ground. As a result, there is an effective elimination of the 50Hz current flowing into the ground, preventing any rise in 50Hz ground potential.

Can you briefly explain the primary differences between Externally Gapped Line Arresters (EGLA) and Non-Gapped Line Arresters (NGLA), and what led RTE to choose EGLA for its applications?

The fundamental distinction between EGLA and NGLA lies in the presence of the arcing gap. EGLAs are essentially Line Surge Arresters (LSAs) that are not perpetually exposed to the system voltage. Instead, their MOV modules only experience stress when a lightning impulse short-circuits the gap. This aspect plays a significant role in the aging process and overall reliability of EGLAs. Conversely, NGLAs are constantly exposed to the system voltage, making them responsive to any form of overvoltage occurring within the network. When designed appropriately, NGLAs offer comprehensive protection against various overvoltages, not just limiting themselves to lightning protection.

Photo: Metarresters

How has the use of EGLA become standardized in France, while still being relatively misunderstood in other countries? What unique factors in France might explain this phenomenon?

As of 2023, France possesses a distinct setup wherein we stand as the sole TSO in France responsible for constructing, maintaining, and operating the High Voltage Power Transmission Network. This centralized approach greatly streamlines the standardization of assets and practices across the country. Although not the only factor, this centralization played a pivotal role in the widespread adoption of EGLA within France. From EGLA's inception, the primary challenge recognized was ensuring the insulation coordination among multiple air gaps: the EGLA's, the insulator strings', and the conductor's to the tower structure. To address this, we adopted a comprehensive approach where a full insulator string, complete with its arcing protections and the EGLA, is assembled. For any new EGLA installation, it isn't just the SVU (Series Varistor Unit) that's added; the entire set replaces the existing insulator string.

We've tailored EGLA sets to cater to various voltage levels, ranging from 63kV to 225kV. These are designed for both suspension and tension towers and can be installed without disrupting service, meaning there's no need for service interruptions when fitting a new EGLA string. This method proves advantageous as it minimizes the need for fresh conceptualizations with each installation, thus ensuring quicker deployment.

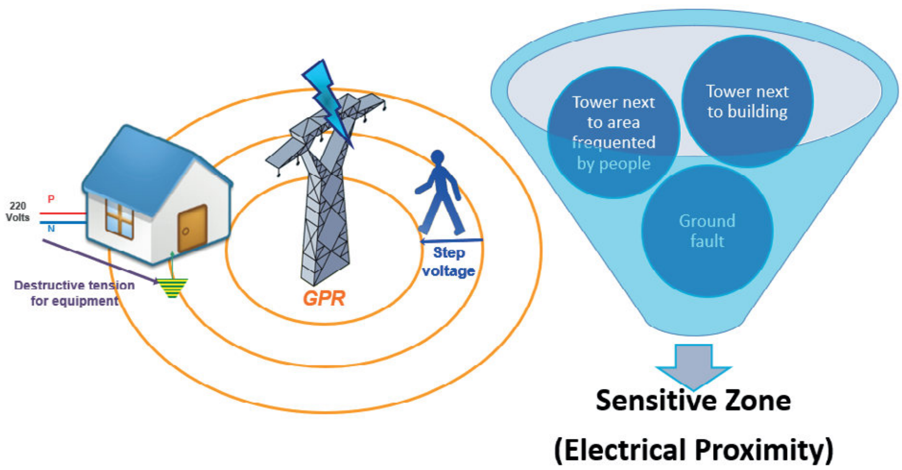
Addressing the latter is achieved through a diverse range of technical solutions tailored to each tower's specific environment. The incorporation of EGLA is merely one of these solutions, but it's one we've heavily invested in, refining it to be as "plug-and-play" as possible for our maintenance and engineering teams.

Could you elaborate on the safety concerns associated with EGLA in France? Why do these concerns seem more prevalent in France than in other countries?

NGLAs are constantly exposed to the system voltage, making them responsive to any form of overvoltage occurring within the network.

When designed appropriately, NGLAs offer comprehensive protection against various overvoltages, not just limiting themselves to lightning protection.

It is important to note that LSAs are predominant worldwide for seeking to reduce network outages related to lightning. This is, of course, one of the uses in France, but the predominant reason for EGLA's usage is to mitigate the risks associated with ground potential rise due to lightning-induced faults. On one hand, post-WWII saw an exponential expansion of transmission line circuits, which originally were distanced from populated areas. Over time, these habitation zones grew closer to the transmission line towers.
On the other hand, we have stringent internal regulations that prioritize the safety of the surroundings adjacent to our networks, encompassing both human safety and structural integrity. The heightened safety concerns in France stem from stringent domestic regulations aimed at ensuring that



our electrical infrastructure does not compromise public safety.
These regulations encompass a wide range of elements, including power lines, towers, cables, and substations. Safety criteria range from mitigating the risk of direct electrical shock to minimizing audible noise, radio interference, and ground potential rise, among other factors.

Are there any statistical data available regarding the failure rate of EGLA within RTE's operations? How does this compare to the global industry standards?

We haven't maintained specific statistics on EGLA failure rates within RTE's operations, primarily because we have not encountered failures with our EGLAs. Therefore, we have not perceived a necessity to monitor this asset's performance closely.
It would be speculative, yet educated, to assume that our EGLAs outperform certain NGLAs that have documented issues, such as failures in ground leads. However, quantitative data to substantiate this claim is currently lacking.

Can you explain how RTE manages to perform installation and maintenance of EGLA in live conditions? Is this practice common for all voltage levels within the network?

RTE executes live-line work for voltage networks ranging from 63kV to 400kV. However, EGLAs are not installed in the 400kV network for primarily two reasons:

- The 400kV network experiences relatively fewer lightning-induced faults. Therefore, if EGLAs were to be implemented, their primary role would be to enhance the line's lightning performance and service reliability.

- Our installation standards mandate that all EGLAs must be compatible with live-line work, or at least permit such work to be carried out in proximity to them. In this context, the SVU is treated as a live component as a conservative safety measure, impacting the safety distances considered during installation. This makes the design of a standard insulation string with an EGLA for the 400kV network more complex, although not technically unfeasible.

For off-service installations, external contractors may be engaged to carry out the work.

For in-service installations, each tower's requirements are meticulously planned by our specialized department.

225kV EGLA – Installation in live conditions (1)

225kV EGLA – Installation in live conditions (2)

Currently, we are in the process of re-evaluating the need to include a 400kV EGLA in our asset catalogue. Future assessments will determine our course of action.

Were there any specific modifications made to RTE's EGLA design to facilitate live line working? If so, could you describe the changes that were made?

Indeed, while the concept is straight forward, its practical implementation poses challenges. Live line work mandates adherence to specific safety distances, particularly as the SVU is treated as a conductive element, akin to metal. To facilitate live line installation of our 225kV EGLA, predecessors in our team engineered a unique system. This system allows for the SVU unit to be installed without violating these safety zones. Specifically, the changes included installing the unit in a horizontal orientation, connecting it to an anchor-ing bar, and incorporating a pivot mechanism. This setup ensures that the EGLA is positioned at the precise distance required for the air gap.

How does RTE's experience with EGLA reflect the overall trends and development in the high-voltage industry in France and beyond?

Generally speaking, RTE's expertise in live line work is garnering recognition and is being adopted by multiple other TSOs. Additionally, it has come to my attention that EGLAs are under consideration in the United States to address ground potential rise risks near buried hydrocarbon metallic conduits.

Can you describe the typical lifecycle of an EGLA within RTE's network, from installation to replacement, and what maintenance strategies are employed to ensure optimal performance?

Photo: Metarresters

Upon receiving a request for EGLA installation, we proceed with the planning phase, during which we determine whether the line will remain in service or be taken off-service for the installation. For off-service installations, external contractors may be engaged to carry out the work. For in-service installations, each tower's requirements are meticulously planned by our specialized department. We do not rely on standardized live-work procedures; each tower is subject to its own unique analysis and strict adherence to safety distances.

Following installation, the EGLAs are generally low-maintenance. Our strategy consists of an annual visual inspection across all our lines. We employ a fault indicator system that activates a red flag when the SVU of the EGLA sustains damage. To date, this fault indicator has only been triggered in a laboratory setting and during one incident over a decade ago, which turned out to be a design failure rather than an issue with the SVU. Subsequently, the design was amended, and we have not experienced any false positives or negative reports of EGLA malfunctions since. Therefore, we have strong evidence to believe that both EGLAs and their associated fault indicators are performing as intended.

What are RTE's plans for the future of EGLA implementation, both in terms of technological advancements and strategic planning?

At present, we have adopted a new fault indicator technology from our existing EGLA manufacturer. While the operational principle is different, the end goal of fault detection is effectively achieved. Future installations of EGLA strings will be equipped with this advanced fault indicator. Moreover, we are currently assessing the demand for a 400kV EGLA solution.

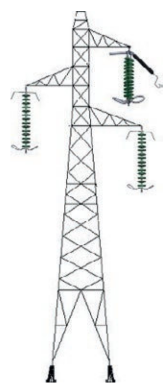
Strategically, we are committed to advocating for the use of EGLAs to mitigate Ground Potential Risks. A key focus is on quantifying the actual risk reduction, which would make it more straightforward to select EGLAs as a cost-effective solution among various options. Additionally, we are promoting EGLAs to enhance the lightning performance of overhead lines that lack shield wires, which account for nearly half of our tower infrastructure.

At RTE, a full protection approach (every phase/every tower) of line sections is not our strategy; instead, we conduct detailed analyses to study various installation configurations tailored to the unique characteristics of each line. Our objective is to achieve optimal performance benefits at reduced costs, supported by feasible installation procedures. To facilitate this, we are continually refining our numerical models employed in Electromagnetic (EM) transient simulations.

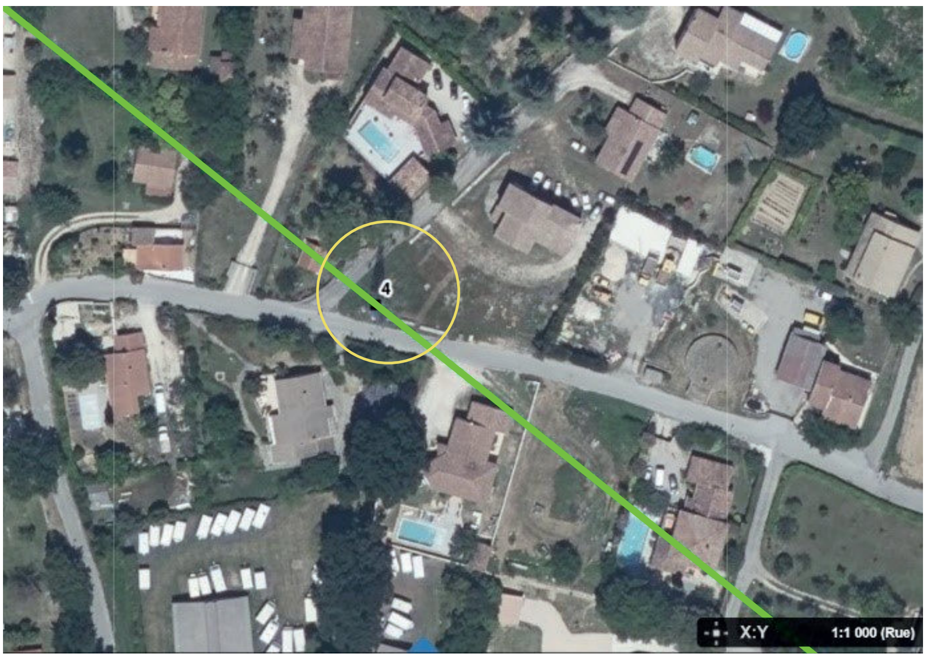
How does RTE's approach to EGLA align with France's energy policies and regulatory landscape?

The deployment of EGLAs within RTE's network is particularly influenced by French legislative mandates that prioritize environmental protection in the vicinity of our towers, as noted earlier.

Future installations of EGLA strings will be equipped with this advanced fault indicator. Moreover, we are currently assessing the demand for a 400kV EGLA solution.



225kV EGLA on the top phase of an unshielded tower – lightning performance



225kV Tower in the vicinity of residential considered as high risk – EGLA installed for safety concerns

Photo: Metarresters

Can you share any interesting case studies or success stories related to EGLA's use in RTE's operations that might illustrate its effectiveness and benefits?

Certainly, we have several noteworthy cases. One involves a 225kV line located to the east of Paris, which was partially fitted with EGLAs on just one of its phases, specifically the section without a shield wire. As a result, the line's average yearly outage rate was reduced by 60%, going from one outage per year to 0.4 outages per year. Another example comes from the South of France, where we have a 225kV line running through a residential area with homes in close proximity, many of which have swimming pools. To mitigate potential risks, all phases of this line are equipped with EGLAs.

What challenges, if any, has RTE faced in the implementation and maintenance of EGLA? How were these challenges overcome?

Challenges in the implementation and maintenance of EGLAs have largely revolved around fault indicators and establishing safe distances for live line installations of EGLA strings. While we haven't delved deeply into the topics of conception and qualification, they are crucial for ensuring appropriate insulation coordination for the air gaps. To meet these requirements, we have made multiple visits to laboratories for testing and modifications after the initial design phase, confirming the effectiveness of the string's design.

Finally, what advice would you offer to other utility providers considering the adoption of EGLA, especially those in countries where this technology is less understood?

It's crucial to understand that EGLAs are not subjected to continuous stress during service, making them highly reliable assets, particularly when Electromagnetic (EM) Transient studies are conducted to accurately determine their energy tolerances. Special attention should be paid during the qualification phase or pre-installation tests.

EGLAs serve as a beacon of innovation, offering significant improvements in both lightning performance and system reliability.

However, they must be carefully integrated into power systems with keen attention to safety standards, affecting both human and material resources.

Conduct tests that closely mirror actual installation conditions. While this approach may be time-consuming, it is a worthwhile investment to ensure you're implementing a technology designed to provide reliable service for several decades.

In summary, the potential for improving lightning performance through the use of EGLAs cannot be overstated. Modern advancements in surge arrester technology, particularly in the area of EGLAs, pave the way for minimizing the risks associated with lightning strikes on power systems. The reduction in flashover rates, coupled with enhanced system reliability, underscores the value these devices bring to the electricity supply industry. However, it is crucial to consider these benefits within the context of safety concerns that could affect both equipment and personnel.

The deployment of EGLAs must adhere to rigorous safety protocols, especially during live line installations. It is imperative that best practices be followed in the selection, installation, and maintenance of EGLAs to fully leverage their potential while also mitigating risks.

Looking beyond mere lightning performance and safety, EGLAs hold promise for various other applications. They could be adapted for use in line compaction, retrofit applications, and enhanced power corridors—developments that are increasingly essential in the context of energy transition.

In conclusion, EGLAs serve as a beacon of innovation, offering significant improvements in both lightning performance and system reliability. However, they must be carefully integrated into power systems with keen attention to safety standards, affecting both human and material resources. As we move forward, the application of EGLAs in broader contexts reveals a bright future, replete with opportunities for further advancements and implementations.

Larry Zulch

CEO at Invinity Energy Storage

Interview with **Larry Zulch**

Photo: Invinity Energy Storage

INVINITY ENERGY SYSTEMS

"Scalability is important. If you have enough small battery systems, they can make a difference. But right now, with large wind farms, large solar installations, they're making so much energy when the wind's blowing, the sun's shining, they don't know what to do with it all. We're curtailing gigawatt hours every year, and then as soon as the sun goes down, there are shortages. That's solved in the hundreds of megawatt-hour range.

Alan Ross: Hi, I'm Alan Ross. I'm the Managing Editor of APC Media, our APC Technology Productions, Transformer Technology, Power Systems Technology. We are here at the RE+ 2023 event in Las Vegas.

My next guest is Larry Zulch. We've had an interview before, Larry. Larry is the CEO of Invinity, an ESS, large Energy Storage System producer. It seems like batteries are now everywhere, right? The whole second floor upstairs at RE+ is battery, battery, battery. A lot of different systems. Talk a little bit about what's changed since the last time we talked a year ago.

Larry Zulch: There's increasing recognition that when the percentage of renewable energy goes up, when RE+ is successful, getting everybody to do wind and solar, the grid gets unstable. That's when you need energy storage, stabilizing the grid by making energy that's produced intermittently available 24/7.

Photo: Invinity Energy Storage

AR There's a lot of different technologies that use the word scalable. That's one of the big challenges for utilities to decide what to do from a scalability standpoint. From a security standpoint, there's a lot of challenges in that scalability.

LZ Well, scalability is important. If you have enough small battery systems, they can make a difference. But right now, with large wind farms, large solar installations, they're making so much energy when the wind's blowing, the sun's shining, they don't know what to do with it all. We're curtailing gigawatt hours every year, and then as soon as the sun goes down, there are shortages. That is not solved by having a megawatt-hour or two. That's solved in the hundreds of megawatt-hour range.

AR One of the problems is capturing that wind and solar. The other problem is using it when you need it and having that, I'm not going to say automatic shut off, but it is almost as the battery storage areas are becoming peaker plants of the future. We're trying to do away with gas peaker plants, but that's an inverter-based system. Talk about the challenges that the inverter-based system is putting on the rest of the assets. I know transformers. Transformers are failing at twice the rate they've been failing because of the inverter-based system. A lot of harmonics in the system. Now you're getting a lot of power quality issues. Is that affecting the storage system?

LZ You brought up a number of important issues there. What I would say is that we work with PCSs (Power Conditioning Systems) that are designed to fit seamlessly into the larger grid system. But getting the stability you're looking for is going to take energy storage of various types all working together. Like anything else, we tend to look at energy storage in a single bucket. But really, there's going to be short and medium and long and ultra-long and seasonal, and all of those are different technologies.

AR Let's switch gears a little bit. Where does Invinity fit in all of that? You know the market; you've got a solution in the market. Where do you fit?

LZ Since we last talked a year ago, Invinity has put in the largest flow batteries in the United States, in Canada, and in Australia. We already have done so in the UK. What we're doing is demonstrating the commercial viability of vanadium flow batteries to be something that doesn't wear out and doesn't catch fire. Lithium batteries are not perfectly appropriate for stationary use. They're terrific. I have them in my car, I have them in my phone, I have them in my watch. But they're not always the right solution, but there has not been an alternative. Even our current product is not a truly viable alternative to lithium for stationary storage. But we are developing that viable alternative in our next version of our product, and that will be one that will be an entirely new ball game for vanadium flow batteries.

INVINITY HAS PUT IN THE LARGEST LOW BATTERIES IN THE UNITED STATES, IN CANADA, AND IN AUSTRALIA. WE ALREADY HAVE DONE SO IN THE UK. WHAT WE'RE DOING IS DEMONSTRATING THE COMMERCIAL VIABILITY OF VANADIUM FLOW BATTERIES TO BE SOMETHING THAT DOESN'T WEAR OUT AND DOESN'T CATCH FIRE.

AR One of the reasons I love talking to you is that you have a factory in Scotland. I was born in Edinburgh, so I'm really akin to it. Is that your only factory?

LZ No, it isn't. We build the core of a flow battery, the so-called cell stack. It has the membranes where the electricity is interchanged with the liquid electrolyte, which flows through, hence flow battery. That's our real intellectual property that we've developed. We do build it right outside Edinburgh, in Bathgate, and in Vancouver, British Columbia, which is the center of electrochemical expertise in North America. It all came out of the paper industry, so a long story, but they developed expertise in electrochemistry to work with bleach to make paper white. That expertise led to fuel cells in Ballard and then led to flow batteries and ultimately to Invinity.

These are our manufacturing facilities, Vancouver and Bathgate. Then we also build the balance of system, the big metal boxes with tanks and pumps. The best supply chain in the world is in China. We build the balance of system in Suzhou, outside of Shanghai, and bring them in. Although, of course, like everyone else, we're looking at onshoring that capability.

AR You talked about the future and what you're developing. Obviously, that's going to be a patented approach.

LZ For the first time in this show, we're showing Mistral, which is the code name for our next-generation battery, designed to be less expensive and able to scale larger than any flow battery before.

AR When will that be coming to the market? How long is it going to take?

LZ End of next year will be first customer ship.

AR Have you got customers lined up?

LZ Yes, we do.

AR You're not allowed to share any of that, are you?

LZ No, I'm not allowed to say exactly who, but what I can tell you is that the interest in it is great, because the limitations of lithium are clear. Therefore, people are hungry for alternatives. We do have a global engineering firm, a very large German and Spanish firm that is supporting the development of this new product. When they say this is a great product and that they've co-developed it with us, we think it'll change the non-lithium storage industry.

AR Storage industry. You use Vanadium, is that correct? Vanadium for most people, if you don't have an engineering degree and you didn't have to take a chemistry course, it sounds very appealing.

LZ My daughter say it sounds like it's out of a Marvel movie. Vanadium is element 23, it's an element. It's more common in the Earth's crust than copper or chrome or lithium or many other things. Vanadium is mainly used to strengthen metals, but it has a unique characteristic: it combines with oxygen in multiple ways. When the connection changes, it stores or discharges energy. Similar in some ways to the process when hydrogen combines with oxygen, which makes water. Vanadium goes through a similar, what's called a redox process, reduction and oxidation. Our batteries take advantage of that.

VANADIUM IS MAINLY USED TO STRENGTHEN METALS, BUT IT HAS A UNIQUE CHARACTERISTIC: IT COMBINES WITH OXYGEN IN MULTIPLE WAYS. WHEN THE CONNECTION CHANGES, IT STORES OR DISCHARGES ENERGY.

AR Excellent. That is a change the world thing because there is a limit to lithium. Who owns it? Where is it? If vanadium is as common as copper, that means it's everywhere, which is a great solution.

LZ 80% of vanadium is made out of post-industrial processes. When you take sulfur out of fuel for ships, you run it through a catalytic bed to do that. What clogs the catalyst?

Photo: Invinity Energy Storage

WE DO HAVE A GLOBAL ENGINEERING FIRM, A VERY LARGE GERMAN AND SPANISH FIRM THAT IS SUPPORTING THE DEVELOPMENT OF THIS NEW PRODUCT. WHEN THEY SAY THIS IS A GREAT PRODUCT AND THAT THEY'VE CO-DEVELOPED IT WITH US, WE THINK IT'LL CHANGE THE NON-LITHIUM STORAGE INDUSTRY.

Photo: Invinity Energy Storage

Vanadium. A catalyst is useless when it's about 18-20% vanadium, which is a great source of vanadium, and that's being extracted in the US, in Asia, in Europe, all over the place.

AR Oh, that's excellent. It's good to interview you again.

LZ Thank you for the opportunity to talk with you.

Creating a Failure Hierarchy for a Dry-Type Transformer

by **Marie Hirzel**

Photo: Shutterstock

Computerized Maintenance Management Systems (CMMS) allow you to track and trend equipment breakdowns through Failure Hierarchies. Once a Failure Hierarchy has been entered into the CMMS for a specific type of equipment, maintenance personnel are able to identify the failure(s) they found during maintenance work, and how they fixed it. A recurring set of similar failures, causes, or remedial actions can then be identified using the CMMS.

This information allows maintenance personnel to apply new preventive maintenance, adjust the frequency of existing preventive maintenance, or make other adjustments (for example, switching to a different type of grease) to address the trend.

The matrix to the right shows the terms I will use in this article, and the various Failure Hierarchy field names for some of the popular CMMS software packages.

To create the Failure Hierarchy for an indoor dry-type transformer, begin by identifying the "Class" and "Subclass" of the equipment. Class identifies the component. Example Classes include: pump, circuit breaker, motor, transformer, etc. The Class for this equipment is "transformer". Subclass consists of an adjective(s) used to uniquely describe the component. Example Subclasses for a transformer include: dry, oil filled, etc. The Subclass for this equipment is "dry".

This information allows maintenance personnel to apply new preventive maintenance, adjust the frequency of existing preventive maintenance, or make other adjustments.

Article Term	Maximo	SAP	Oracle
Class	Location / Class	Catalog Description	Asset
Subclass	Subclass	Object Part	Child Asset
Problem	Problem	Problem	Failure Sets
Cause	Cause	Cause	
Remedy	Remedy	Action	

Marie Hirzel is a Quality Assurance and Reliability Consultant with 40 years of experience in both the public and private sectors. She specializes in reliability centered maintenance, QA program development and implementation, root cause analysis, assessments (management, program, and implementation), training materials development, benchmarking, failure modes and effects analysis, and technical documents/data creation. She obtained her BSE in Nuclear Engineering from the University of Michigan. She is a Certified Maintenance and Reliability Professional; and is a member of the American Nuclear Society.

FMEA Failure Mode	FMEA Cause
Loose Cable/ Connections	INDUCED - Incorrect installation
	WEAR OUT - Due to age, heat, and vibration
Connection or Cable Failure	INDUCED - Dirt or other contaminant build-up
	INDUCED - Electrical or thermal overload
	WEAR OUT - Corrosion or other age related degradation
Transformer Insulation Failure	INDUCED - Electrical or thermal overload
	WEAR OUT - Age related degradation
Transformer Winding Failure	WEAR OUT - Age related degradation
	INDUCED - Electrical or thermal overload
Cooling System Failure	INDUCED - Dirt, corrosion, or other contaminant build-up
	INDUCED - Insufficient fan lubrication
	INTERMITTENT - Temperature relay or fan motor starting switch failure
	WEAR OUT - Age related degradation

Failure Hierarchies are typically created for each subclass. The simplest way to create the Failure Hierarchy is from a Failure Modes and Effects Analysis (FMEA). For instructions on how to perform an FMEA, refer to the article entitled "Performing a Failure Modes and Effects Analysis on a Dry-Type Transformer" in the June 2019 issue of Transformer Technology Magazine. I will use the FMEA created in that article to write the Failure Hierarchy. The pertinent fields from that FMEA are "Failure Mode" and "Cause" which are shown above.

For the Class/Subclass of Dry Transformer, I will now populate the remaining 3 Failure Hierarchy fields:

FAILURE	CAUSE	REMEDY

There can be multiple "Failures", multiple "Causes" for each "Failure", and multiple "Remedies" for each "Cause". I will begin by using the Failure Modes from the FMEA to populate the "Failure" field in the Hierarchy. The first 2 Failure Modes, "Loose Cable/Connections" and "Connection or Cable Failure", can be combined into a single Failure of "Transformer Cable/Connection Failure". The remaining 3 Failure Modes can be entered as is, resulting in the following entries:

FAILURE
Transformer Cable/Connection Failure
Transformer Forced Air Cooling Failure
Transformer Insulation Failure
Transformer Windings Failure

The simplest way to create the Failure Hierarchy is from a Failure Modes and Effects Analysis.

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Next, I will use the FMEA Causes to write the Failure Hierarchy Causes. For the Hierarchy Failure "Transformer Cable/Connection Failure", the applicable FMEA Causes are:

FMEA Failure Mode	FMEA Cause
Loose Cable/ Connections	INDUCED - Incorrect installation
	WEAR OUT - Due to age, heat, and vibration
Connection or Cable Failure	INDUCED - Dirt or other contaminant build-up
	INDUCED - Electrical or thermal overload
	WEAR OUT - Corrosion or other age-related degradation

Three FMEA Causes come directly over:

- Incorrect installation
- Dirt or other contaminant build-up
- Electrical or thermal overload

The remaining FMEA Causes are for "age" and "corrosion". In the Failure Hierarchy, corrosion can be added as-is, but I list age related degradation as "damage". Last, I will add a Cause for a "loose connection" as follows:

- Cable/Connection Corroded
- Cable/Connection Damaged
- Loose Connection

The complete list of Failure Hierarchy Causes for "Transformer Cable Connection Failure" then becomes:

FAILURE	CAUSE
Transformer Cable/ Connection Failure	Cable/Connection Corroded
	Cable/Connection Damaged
	Dirt or Contaminant Build-Up
	Electrical or Thermal Overload
	Incorrect Installation
	Loose Connection

I'm going to write the Causes for the Failure Mode "Transformer Forced Air Cooling Failure" next. The applicable FMEA Causes are:

FMEA Failure Mode	FMEA Cause
Cooling System Failure	INDUCED - Dirt, corrosion, or other contaminant build-up
	INDUCED - Insufficient fan lubrication
	INTERMITTENT - Temperature relay or fan motor starting switch failure
	WEAR OUT - Age related degradation

These FMEA Causes come directly over, with age related degradation listed as damage:

- Dirt/Contaminant Build-Up
- Insufficient Grease
- Fan Electronic Controls Failure
- Fan Damaged

Giving us:

FAILURE	CAUSE
Transformer Cable/ Connection Failure	Cable/Connection Corroded
	Cable/Connection Damaged
	Dirt or Contaminant Build-Up
	Electrical or Thermal Overload
	Incorrect Installation
	Loose Connection
Transformer Cable/ Connection Failure	Dirt/Contaminant Build-Up
	Insufficient Grease
	Fan Electronic Controls Failure
	Fan Damaged

Moving on to the next Failure Mode, "Transformer Insulation Failure", the applicable FMEA Causes are:

FMEA Failure Mode	FMEA Cause
Transformer Insulation Failure	INDUCED - Electrical or thermal overload
	WEAR OUT - Age related degradation

In the Failure Hierarchy, I express age related degradation as "damage". These Causes then become:

- Electrical or Thermal Overload
- Insulation Physically Damaged

Giving us:

FAILURE	CAUSE
Transformer Cable/ Connection Failure	Cable/Connection Corroded
	Cable/Connection Damaged
	Dirt or Contaminant Build-Up
	Electrical or Thermal Overload
	Incorrect Installation
	Loose Connection
Transformer Forced Air Cooling Failure	Dirt/Contaminant Build-Up
	Insufficient Grease
	Fan Electronic Controls Failure
	Fan Damaged
Transformer Insulation Failure	Electrical or Thermal Overload
	Insulation Physically Damaged

The Remedies are standard repair practices for dry-type transformers used by electrical maintenance crews.

Photo: Comcast

For the final Failure Mode "Transformer Windings Failure", the applicable FMEA Causes are:

FMEA Failure Mode	FMEA Cause
Transformer Winding Failure	WEAR OUT - Age related degradation
	INDUCED - Electrical or thermal overload

In the Failure Hierarchy, these Causes become:

- Electrical or Thermal Overload
- Windings Physically Damaged

This completes the first 2 fields of our Failure Hierarchy:

FAILURE	CAUSE
Transformer Cable Connection Failure	Cable/Connection Corroded
	Cable/Connection Damaged
	Dirt or Contaminant Build-Up
	Electrical or Thermal Overload
	Incorrect Installation
	Loose Connection
Transformer Forced Air Cooling Failure	Dirt/Contaminant Build-Up
	Insufficient Grease
	Fan Electronic Controls Failure
	Fan Damaged
Transformer Insulation Failure	Electrical or Thermal Overload
	Insulation Physically Damaged
Transformer Windings Failure	Electrical or Thermal Overload
	Windings Physically Damaged

Finally, I will write the "Remedies" for each Cause. The Remedies are standard repair practices for dry-type transformers used by electrical maintenance crews, which the FMEA does not contain. These are written in past tense because the electrician will select the Remedy implemented after the work has been completed, not before. Examples of common Remedies include greasing a fan, cleaning a connection, replacing a cable, etc.

Beginning with the "Transformer Cable/Connection Failure", and first Cause "Cable/Connection Corroded", there are 2 possible Remedies:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
		Replaced the Cable/Connection

For the same Failure, second Cause of "Cable/Connection Damaged", there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
		Replaced the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection

For the same Failure, third Cause of "Dirt or Contaminant Build-Up", there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
		Replaced the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Cleaned the Connection

For the same Failure, fourth Cause of "Electrical or Thermal Overload", there is also only one Remedy:

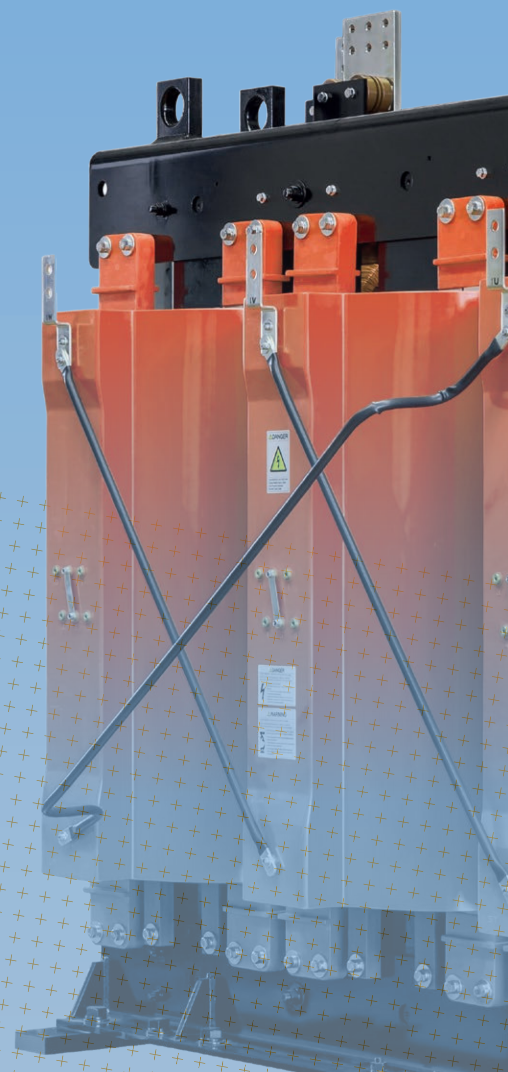
FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
		Replaced the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Cleaned the Connection
	Electrical or Thermal Overload	Replaced the Cable/Connection

For the same Failure, fifth Cause of "Incorrect Installation", again, there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
		Replaced the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Cleaned the Connection
	Electrical or Thermal Overload	Replaced the Cable/Connection
	Incorrect Installation	Installed Correct Cable and Terminations

For the same Failure, sixth Cause of "Loose Connection", once again, there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
		Replaced the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Cleaned the Connection
	Electrical or Thermal Overload	Replaced the Cable/Connection
	Incorrect Installation	Installed Correct Cable and Terminations
	Loose Connection	Tightened Connection



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For the same Failure, sixth Cause of "Loose Connection", once again, there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
		Replaced the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Cleaned the Connection
	Electrical or Thermal Overload	Replaced the Cable/Connection
	Incorrect Installation	Installed Correct Cable and Terminations
	Loose Connection	Tightened Connection

Moving on to the "Transformer Forced Air Cooling Failure", for the first Cause "Dirt/Contaminant Build-Up", there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Forced Air Cooling Failure	Dirt/Contaminant Build-Up	Cleaned and Repaired Fan

For the same Failure, second Cause of "Insufficient Grease", there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Forced Air Cooling Failure	Dirt/Contaminant Build-Up	Cleaned and Repaired Fan
	Insufficient Grease	Greased Fan

For the same Failure, third Cause of "Fan Electronic Controls Failure", there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Forced Air Cooling Failure	Dirt/Contaminant Build-Up	Cleaned and Repaired Fan
	Insufficient Grease	Greased Fan
	Fan Electronic Controls Failure	Replaced Fan Controls

For the same Failure, fourth Cause of "Fan Damaged", there are two Remedies:

FAILURE	CAUSE	REMEDY
Transformer Forced Air Cooling Failure	Dirt/Contaminant Build-Up	Cleaned and Repaired Fan
	Insufficient Grease	Greased Fan
	Fan Electronic Controls Failure	Replaced Fan Controls
	Fan Damaged	Repaired Fan
		Replaced Fan

Moving on to the "Transformer Insulation Failure", for the first Cause "Electrical or Thermal Overload", there are three possible Remedies:

FAILURE	CAUSE	REMEDY
Transformer Insulation Failure	Electrical or Thermal Overload	Replaced the Insulation
		Replaced the Windings
		Replaced the Transformer

For the same Failure, second Cause of "Insulation Physically Damaged", the same three possible Remedies exist:

FAILURE	CAUSE	REMEDY
Transformer Insulation Failure	Electrical or Thermal Overload	Replaced the Insulation
		Replaced the Windings
		Replaced the Transformer
	Insulation Physically Damaged	Replaced the Insulation
		Replaced the Windings
		Replaced the Transformer

Moving to the "Transformer Windings Failure", for the first Cause "Electrical or Thermal Overload", there are two possible Remedies:

FAILURE	CAUSE	REMEDY
Transformer Windings Failure	Electrical or Thermal Overload	Replaced the Windings
		Replaced the Transformer

For the same Failure, second Cause of "Windings Physically Damaged", the same two possible Remedies exist:

FAILURE	CAUSE	REMEDY
Transformer Windings Failure	Electrical or Thermal Overload	Replaced the Windings
		Replaced the Transformer
	Windings Physically Damaged	Replaced the Windings
		Replaced the Transformer

This completes the Failure Hierarchy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
		Replaced the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Cleaned the Connection
	Electrical or Thermal Overload	Replaced the Cable/Connection
	Incorrect Installation	Installed Correct Cable and Terminations
	Loose Connection	Tightened Connection
Transformer Forced Air Cooling Failure	Dirt/Contaminant Build-Up	Cleaned and Repaired Fan
	Insufficient Grease	Greased Fan
	Fan Electronic Controls Failure	Replaced Fan Controls
	Fan Damaged	Repaired Fan
		Replaced Fan
Transformer Insulation Failure	Electrical or Thermal Overload	Replaced the Insulation
		Replaced the Windings
		Replaced the Transformer
	Insulation Physically Damaged	Replaced the Insulation
		Replaced the Windings
		Replaced the Transformer
Transformer Windings Failure	Electrical or Thermal Overload	Replaced the Windings
		Replaced the Transformer
	Windings Physically Damaged	Replaced the Windings
		Replaced the Transformer

It is ready to be entered into the CMMS and used to adjust your dry-type transformer maintenance strategy, making it more effective and resulting in better reliability.

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Mark Culpepper

Photo: Zeitview

Interview with **Mark Culpepper**

General Manager Solar Solutions
at Zeitview, Global

"Our approach to solar has always been, if we're not serving this market at scale, we're really not serving the market at all, because this market requires scale and it requires the efficiencies that come with scale.

Alan Ross: Hi, I'm Alan Ross. I'm the Managing Editor of APC Media, our APC Technology Productions, Transformer Technology, Power Systems Technology. We are here at the RE+ 2023 event in Las Vegas. This thing is huge. We've got wind, solar, battery storage, and everything in between. I hope you enjoy these interviews.

My next guest is Mark Culpepper. Mark, good to meet you. You are the General Manager for global solar solutions for the company Zeitview. There are some things about that that are very unique. First of all, how long have you been in the industry and how did you get in the industry?

Mark Culpepper: I started out in solar back in late 2005.

AR Oh, my gosh! You're like a legacy guy, right?

MC Yeah, an OG, I guess you could call me. I started out in 2005 working for what was considered a large-scale EPC developer at that time, which was Team - Solar out of Sacramento. They did a one-megawatt tracker, which was considered substantial at the time. I originally started out as the head of business development. We sold the business to Sun Edison not too long after I came on board. Then at Sun, I initially ran marketing. I did all the global go-to-market. Then, because of my background in tech, I just started taking over a lot of the technology projects. The first one I took over was our Workflow System. I built the Workflow System in-house. Then after that, they said, *Mark, you're pretty good at this one. Would you be our CTO and build out our global O&M and asset management function?* I did all that work and basically that's where I ended up. I built out the global operations and maintenance business for the company and the asset.

AR Management function. That was Sun Edison?

MC That was Sun Edison. I left in late 2011.

Now I'm with Zeitview. Our tagline at Zeitview is "advancing inspection."

AR First of all, because of your background as a CTO, talk a little bit about what's happening in the industry. What are the challenges? We're seeing a lot of innovation, probably 90% of the innovative companies who are not going to make it. We just see a lot of change.

MC I think the biggest challenge the industry faces right now is labor. There literally are not enough people to do the work that we find. We do inspections. What we're finding is that there are companies that just can't move quick enough to actually close the gap between what they're seeing in the field and what we're revealing to them and what they need to deliver for their clients. That labor gap is real. I don't think that's going to go away. I think it's actually becoming more acute. Anything that companies are doing to help focus and tune that has got a lot of value. Making labor more efficient. That's through automation technologies, through a number of other aspects. But automation is absolutely foundational to that whole problem.

The biggest challenge the industry faces right now is labor. There literally are not enough people to do the work that we find. Automation is absolutely foundational to that whole problem.

AR I love the idea that you solve a labor problem with automation, digitalization, data management. I have a philosophy. Let the machine talk. Let it tell you what the issue is, and somehow inspections do that. You mentioned that you're in the inspection business. Is that infrared? How is that used?

MC We do both what's called thermal or infrared inspections, typically called infrared, but thermal is probably a little more accurate, and visual or RGB inspections. We're pretty agnostic. We don't really care if you use a crewed aircraft, typically an airplane, a drone, or boots on the ground. It really doesn't matter to us. We'll use any one of those as tools to solve the problem. For the clients, they don't really care either at the end of the day. They're trying to basically get their assets inspected and get them prepped for the next high production season or take corrective action in many cases. They don't care how you collect the data.

AR What is a high production season?

MC As we orbit around the globe, you've got this oscillation of sunlight that plays out over the course of the year. The peak of that - the high production season - is during the summer months. That's where you've got to make sure your systems are really primed and are producing. If you come into late winter, early spring and your systems are really degraded and you're not ready for that peak production period, you're going to lose a lot of money that would have gone into

Photo: Shutterstock

your pocket. Making sure that your field teams are ready to actually get that work done and that they've got a plan of attack when they go into that season is really key.

As we orbit around the globe, you've got this oscillation of sunlight that plays out over the course of the year. The peak of that – the high production season – is during the summer months. That's where you've got to make sure your systems are really primed and are producing.

AR The other part of that is labor shortage. Those field crews that have to go into the field to do that. How do you help solve that problem, if at all?

MC That's a great question. Our entire mode has been, how we like to say, *How do you get to the cheese quickly?* How do you get to it quickly? We know from our own research that field teams spend 10-15% of the time just trying to find the problem. At a different level, though, if you look at a lot of portfolios, we just completed the North American Solar Scan. We scanned every solar asset thermally and visually in the lower 48 from 1 megawatt and above.

AR That fascinates me. How did you do that? What does that mean and who paid for it?

MC We paid for it. That entire exercise was done with crewed aircraft. It was about 95 gigawatts and over 6,200 sites. It took us a little longer than we wanted to take this first year. We had some weather issues in California. I don't know if you heard about that. We got absolutely hammered. There were 13 storms just back-to-back. That really threw our schedule off a little bit. But the net of it is that from that scan, we were able to determine which assets were performing well and which assets were performing not as well as we would have liked, and which assets were truly distressed.

Photo: Shutterstock, Zeitview

AR Connect that for me. When you're doing the solar scans and you're in a crewed aircraft, how do you determine that an asset is not effectively operating?

MC When you scan a solar array or even a solar panel that's producing energy, when you have a disconnected component, say an individual cell, maybe it's got a broken linkage, that cell is still generating energy, but it doesn't have anywhere to push it. That energy gets translated into heat energy. When you hit it with a thermal camera, that heat spot shows up really, really bright. That's true not only for a cell inside a module, but also for a string of modules put together. It's also true for an invertor that might be offline or large portions of an entire power plant. The whole power plant will have an elevated temperature where it's disconnected from the grid. It allows us to very easily identify where those defects or challenges are. Sometimes they're not defects, sometimes they're just components that haven't been connected for whatever reason. It allows us to then direct the crews to the right location. Now, typically, what will happen in this industry is that when the inspection is requested, they'll say, *Hey, I've got a portfolio of 100 sites, can you inspect these?* Historically, that's how the industry is operated.

We would go out and inspect those assets. Then once we're done inspecting those assets, we generate reports, comprehensive reports that tell you that you have this many cell defects, you have this many diodes out, you have this many modules that are offline, the whole nine yards. Well, when you're scanning the entire United States, you don't necessarily want to have that much detail for the entire portfolio report, because the portfolio is 6,200 sites. What we did was we came up with a new reporting structure called the solar asset rating. You can think of the solar asset rating very much like a bond rating. We rate it triple A all the way to triple D. It's very simple. It allows you to look at an asset and determine the asset is in good condition, or that the asset has issues, or that it is distressed.

We came up with a new reporting structure called the solar asset rating. We rate it triple A all the way to triple D. It's very simple. It allows you to look at an asset and determine the asset is in good condition, or that the asset has issues, or that it is distressed.

Now, what that allows the clients to do is very quickly look at their portfolios and set their standard however they want, triple B, triple A, whatever they want to. But if they say triple B and above, they can take those assets, set them to the side and say those assets are in pretty good shape. Rather than deploying my very limited labor force out to fix basically something that's not broken, I can now focus on the assets that actually do have issues. From those assets, you can generate a comprehensive analysis that says, tell me exactly where the problems are at this asset, be it string level issues, harnesses, combiner boxes, all that good stuff. That allows them to get the crews onto that site.

Then the last piece is a mobile app that allows literally the crew to go, *This block right here is costing us $10,000 a year in losses*. Now I can get that crew all the way down from this really big problem down to one particular problem at one particular power plant in one particular section of the plant.

Rather than deploying my very limited labor force out to fix basically something that's not broken, I can now focus on the assets that actually do have issues.

I really believe that this process will allow our overall labor problem, or at least for maintenance anyway, to really make a lot of progress. We have some clients where 70% of their portfolio is in great shape. They don't need to be running crews out there to chase ghosts. This allows them to really focus that energy on the areas where they really do need to put their attention and get that portfolio back up to a level of performance that the overall portfolio owner wants to see.

AR I am the chairman of the Smart Grid Reliability Association, and we're big on safety and reliability. One of the things that we focus on is stopping doing maintenance on things that don't need it and focus your maintenance on the places where you do. The Department of Energy, combined with OSHA, actually looked at what's changing in the labor market. They started in 2021, and they said there will be a 5.3% attrition of labor in maintenance. They're retiring and they're going away. They also predict an 8,5% growth every year, annually. Since 2021, we've been in a 13% deficit, and it's just getting worse. This solves the problem, as it enables working on what needs work and not wasting energy. That's brilliant. I appreciate that.

Lastly, let's talk a little bit about the company and what you see for where you're going.

Photo: Zeitview

MC Zeitview does inspections. We do advanced inspections on high-value infrastructure, and we focus on five verticals: solar, wind, transmission & distribution, telecom, and properties. Of those, obviously, wind, solar, T&D, and properties are very tightly correlated. I was just at a solar plant yesterday just east of Las Vegas. It's about a gigawatt of solar. They probably have more of 20 miles of feeder lines. Those feeder lines have to be inspected. They have 1.8 million solar panels at that plant. The scale is mind-blowing. Literally, you drive for 20 minutes. The plant is 6 miles long, 3 miles across. You can drive for 20 minutes and not be halfway across the plant. Then you realize this is a very large plant. We're built for those scale of operations, whether it's in solar, wind, or the other verticals that we serve. Our approach to solar has always been, if we're not serving this market at scale, we're really not serving the market at all, because this market requires scale and it requires the efficiencies that come with scale. A big part of our North American Solar Scan was driving that point home, taking a look at the entire asset base in the US, and determining the condition state of the asset bas and how that is actually going to be served over the course of the next several years.

That 13% gap that you talk about in labor? That's not going away. It's going to get worse before it gets better. If we're not efficient, if we're not trying to automate where we can, we're going to find ourselves falling short.

If we're not efficient, if we're not trying to automate where we can, we're going to find ourselves falling short.

AR One of the things of doing these interviews, I meet a lot of different people, and it seems like there are three different tranches of people. Those that are looking for financing, that's going to be hard, everybody's looking for that. They're not going to get a big government grant, because that's going to go to the people that have a proven technology that now needs scale.

Then there's the ones that are at scale and they're the ones that the money is going to flow to and really change the grid. I just think that's phenomenal that you did that whole thing on your nickel. Kind of says, *Guys, we're at scale. You need to get with us*. Well done.

MC Thank you, Alan.

AR Thank you, Mark. My pleasure.

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INSULATION SYSTEMS: OIL, FLUIDS, SOLIDS AND COOLING

Every year, our December issue grows as oils & fluids continue to change. Natural and synthetic esters are taking a greater share of the market and carbon-based insulating fluids are also changing to meet new demands for greater insulation, while solid insulation in everything from transformers to cables is also adapting to increase the reliability and resilience of the power system.

Join us as we delve into the latest advancements, cutting-edge technologies, and innovative approaches shaping the future of insulation in power systems. We invite experts, researchers, and industry professionals to contribute their valuable insights by writing an article for this special edition. Contact our Editor in Chief Alan Ross at alan.ross@apc.media.

COMING IN DECEMBER ISSUE