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TRANSFORMER TECHNOLOGY MAG

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NORTHERN TRANSFORMER'S EVOLUTION: THE DIGITAL SOLUTION FOR POWER TRANSFORMERS

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Chris Rutledge and **Tyler Willis** on DGA Technology for Tap Changers

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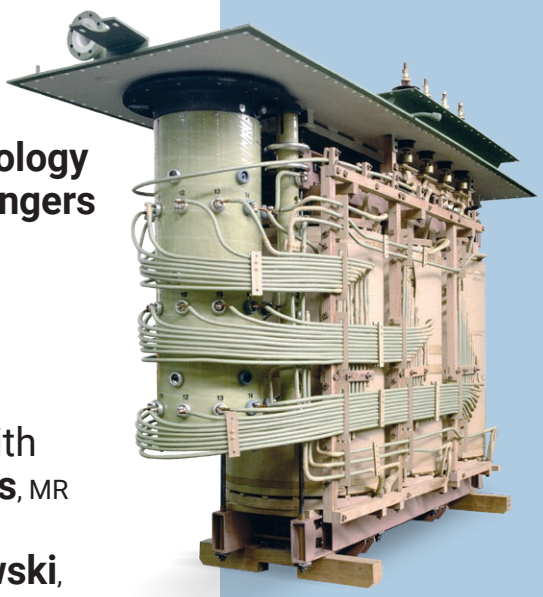

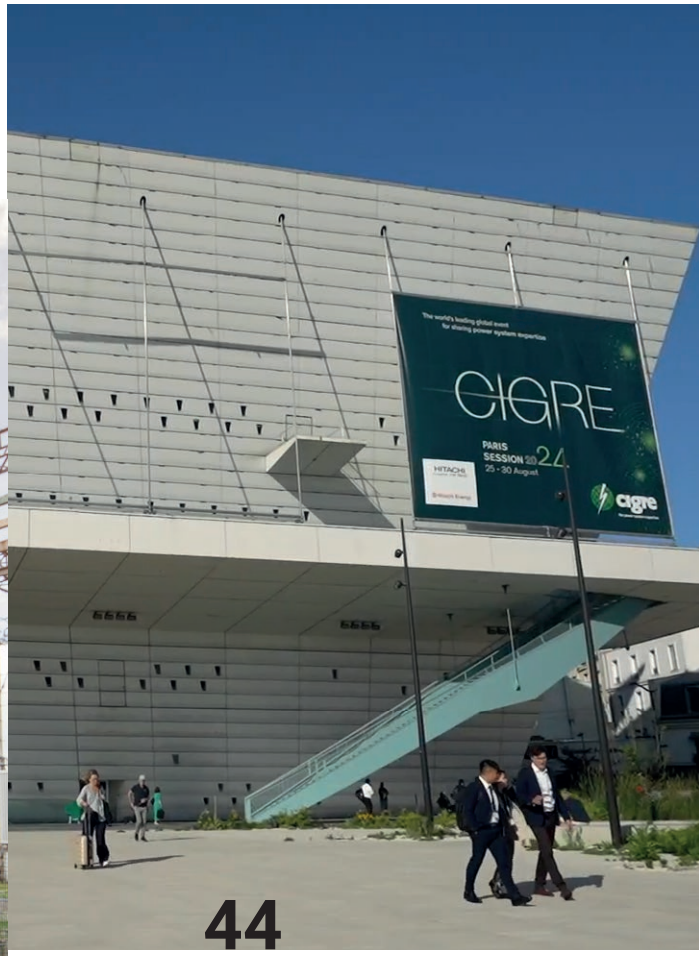

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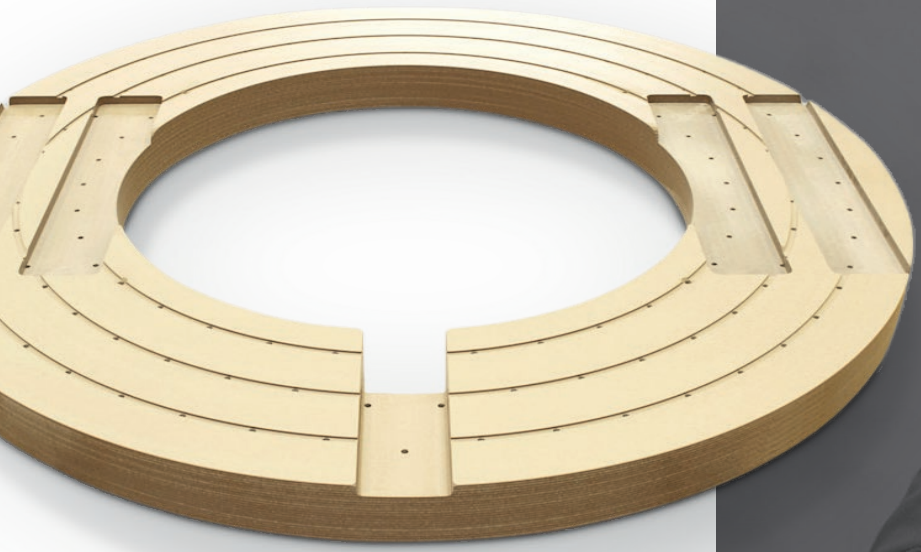

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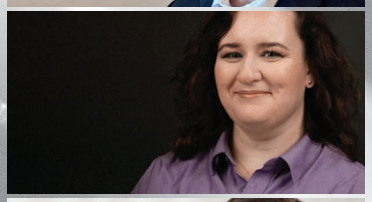

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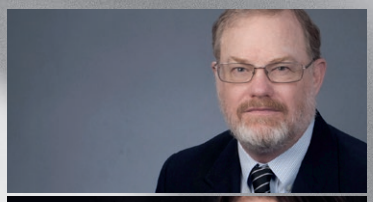

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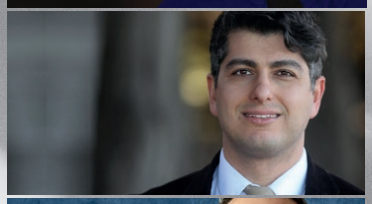

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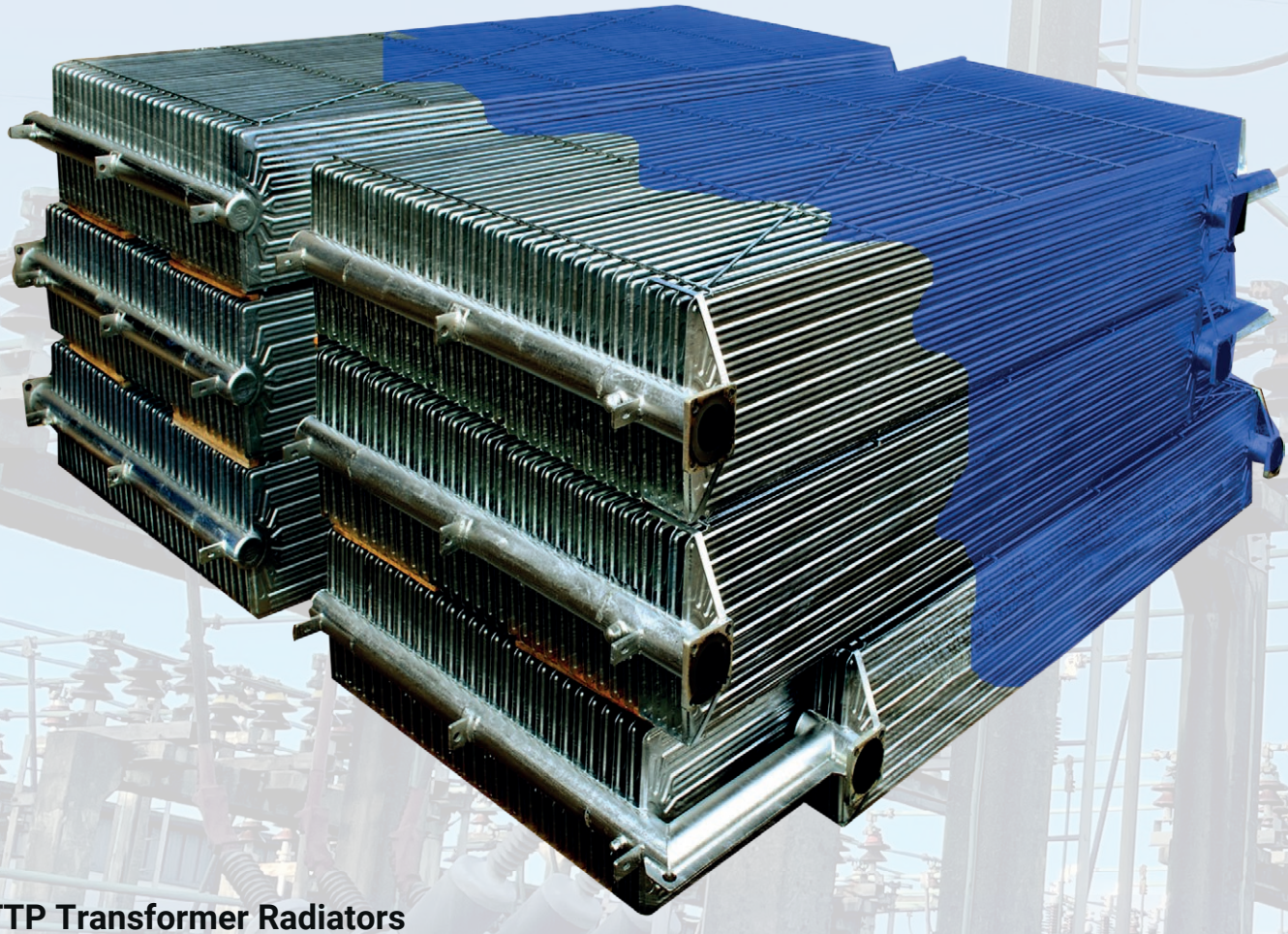

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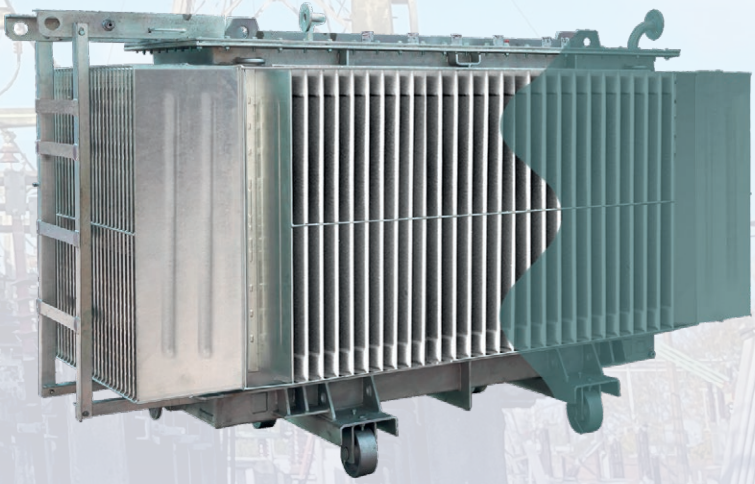

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Navigating the Challenges in the Power Industry's Evolution

The power industry, a cornerstone of modern civilization, is undergoing a transformative phase driven by innovation. This transformation is not just a response to the growing demand for energy but also a proactive approach to address environmental concerns, economic pressures, and the need for sustainable development.

The current state of innovation in the power industry is characterized by advancements in renewable energy technologies, smart grid development, energy storage solutions, and digitalization.

One of the most significant areas of innovation is in renewable energy; solar and wind power have seen remarkable advancements in efficiency and cost reduction. Solar photovoltaic (PV) technology, for instance, has evolved to the point where it is now one of the cheapest sources of electricity in many parts of the world.

Innovations in materials, such as perovskite solar cells, promise even greater efficiencies and lower costs in the near future.

Wind energy has also benefited from technological advancements, with modern turbines becoming larger, more efficient, and capable of generating power even in low-wind conditions. Offshore wind farms, in particular, are gaining traction, with countries like the UK, Germany, and China leading the way in harnessing the vast potential of ocean winds.

Energy storage is another critical area of innovation. The intermittent nature of renewable energy sources like solar and wind necessitates reliable storage solutions to ensure a stable power supply. Lithium-ion batteries have dominated the market, but their limitations in terms of cost, lifespan, and environmental impact have spurred research into alternative technologies. Solid-state batteries, flow batteries, and even hydrogen storage are being explored as potential game-changers. The development of large-scale energy storage systems is crucial for the integration of renewables into the grid and for providing backup power during peak demand periods or emergencies.

The concept of the smart grid represents a paradigm shift in how electricity is distributed and consumed. Traditional power grids are often inefficient and prone to outages. In contrast, smart grids leverage digital technology to enhance the reliability, efficiency, and sustainability of electricity distribution. Advanced metering infrastructure (AMI), real-time monitoring, and automated control systems enable utilities to better manage supply and demand, reduce losses, and quickly respond to faults.

Consumers also benefit from smart grids through greater control over their energy usage and the potential for cost savings. The integration of distributed energy resources (DERs), such as rooftop solar panels and home energy storage systems, into the smart grid further enhances its resilience and flexibility.

> **Renewable energy technologies, energy storage solutions, smart grids, and digitalization are driving a transformation that has the potential to create a more sustainable, reliable, and efficient energy system. However, realizing this potential requires addressing the economic, regulatory, and social challenges that accompany such a profound shift.**

Photo: Shutterstock

Digitalization is playing a pivotal role in driving innovation across the power industry. The use of big data, artificial intelligence (AI), and the Internet of Things (IoT) is transforming how power plants operate and how energy is managed. Predictive maintenance, powered by AI and machine learning, allows for the early detection of potential equipment failures, reducing downtime and maintenance costs. IoT devices enable real-time monitoring and control of energy systems, from individual appliances to entire power plants. Blockchain technology is also being explored for its potential to facilitate peer-to-peer energy trading and enhance the security of energy transactions. The interview outlining the collaboration between MR and Northern Transformer I this issue is a great example of innovation within the need for digitalization.

Despite these advancements, the power industry faces several challenges. The transition to a low-carbon energy system requires significant investment in infrastructure, research, and development. Regulatory frameworks need to evolve to support innovation while ensuring the reliability and affordability of energy. There is also the challenge of ensuring a just transition, where the benefits of innovation are equitably distributed, and the negative impacts on workers and communities dependent on traditional energy industries are mitigated.

At APC Media, we believe that the current state of innovation in the power industry is both promising and complex. Renewable energy technologies, energy storage solutions, smart grids, and digitalization are driving a transformation that has the potential to create a more sustainable, reliable, and efficient energy system. However, realizing this potential requires addressing the economic, regulatory, and social challenges that accompany such a profound shift. The power industry stands at a crossroads, with innovation paving the way towards a brighter and more sustainable future, and at Power Systems Technology, we at APC Media will be right there to share the changes.

Consumers also benefit from smart grids through greater control over their energy usage and the potential for cost savings. The integration of distributed energy resources (DERs), such as rooftop solar panels and home energy storage systems, into the smart grid further enhances its resilience and flexibility.

DGA Technology for Tap Changers: Improving Condition Monitoring and Preventing Transformer Failures

by **Chris Rutledge**
and **Tyler Willis**

As 26% of transformer failures are attributed to On-Load Tap Changers (OLTCs), a reassessment of the relationship between DGA and OLTCs stands to save stakeholders considerable time and resources.

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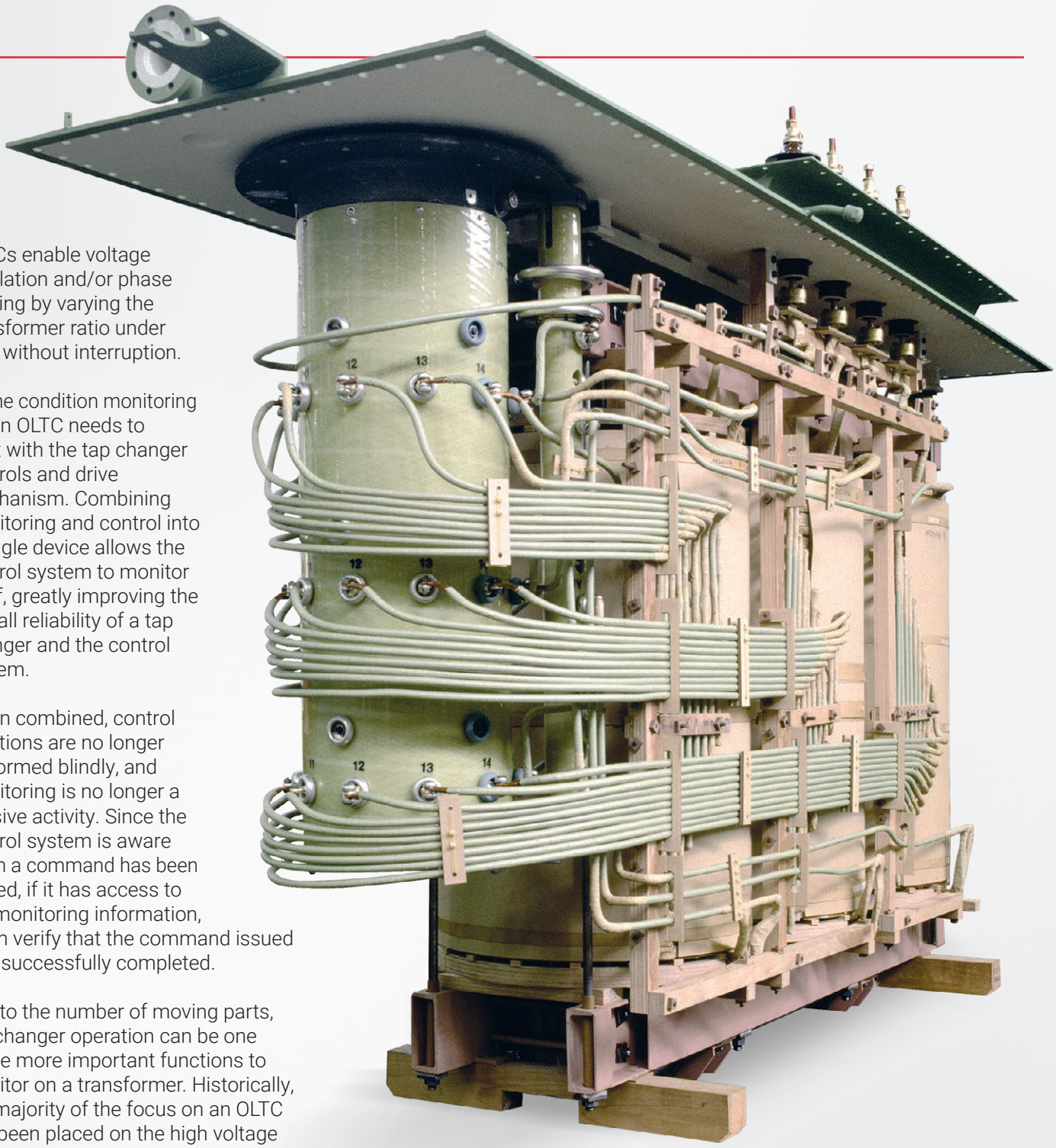
Chris Rutledge is currently a Product Manager at Dynamic Ratings, Inc. He joined the Dynamic Ratings team in July 2019. Prior to his present position, he served as Substation Asset Manager and chairman of the Substation Safety Committee at Memphis, Light, Gas and Water. He has 27 years of experience in the utility industry, primarily focused on the installation, service and maintenance of both substation and distribution equipment. He has done extensive research and published multiple papers concerning the interpretation of dissolved gas analysis testing. Chris is dedicated to assisting customers in finding creative cost-effective solutions for improving safety and reliability across their entire electrical system.

Tyler Willis is a former magazine editor and teacher. He holds a Master's degree in English from the University of Toronto. He is the Founder of Sterling Content, a content solutions company. Tyler has worked in SEO Writing since before SEO Writing existed and has over 20 years of experience in Content Strategy, SEO Project Management, as well as B2B & B2C Copywriting.

Historically, DGA testing of tap-changers has not been considered particularly useful due to the large number of gases normally generated by the arcs. This position has been reconsidered in recent years, and the opinion today is that a considerable amount of data is gained by DGA testing of tap-changers.

As 26% of transformer failures are attributed to On-Load Tap Changers (OLTCs), a reassessment of the relationship between DGA and OLTCs stands to save stakeholders considerable time and resources.

DGA testing is necessary to understand the internal condition of any On-Load Tap Changer, and this article will highlight the benefits of monitoring OLTC compartments with DGA technology to further improve oversight of this crucial compartment.



OLTCs enable voltage regulation and/or phase shifting by varying the transformer ratio under load without interruption.

Online condition monitoring for an OLTC needs to start with the tap changer controls and drive mechanism. Combining monitoring and control into a single device allows the control system to monitor itself, greatly improving the overall reliability of a tap changer and the control system.

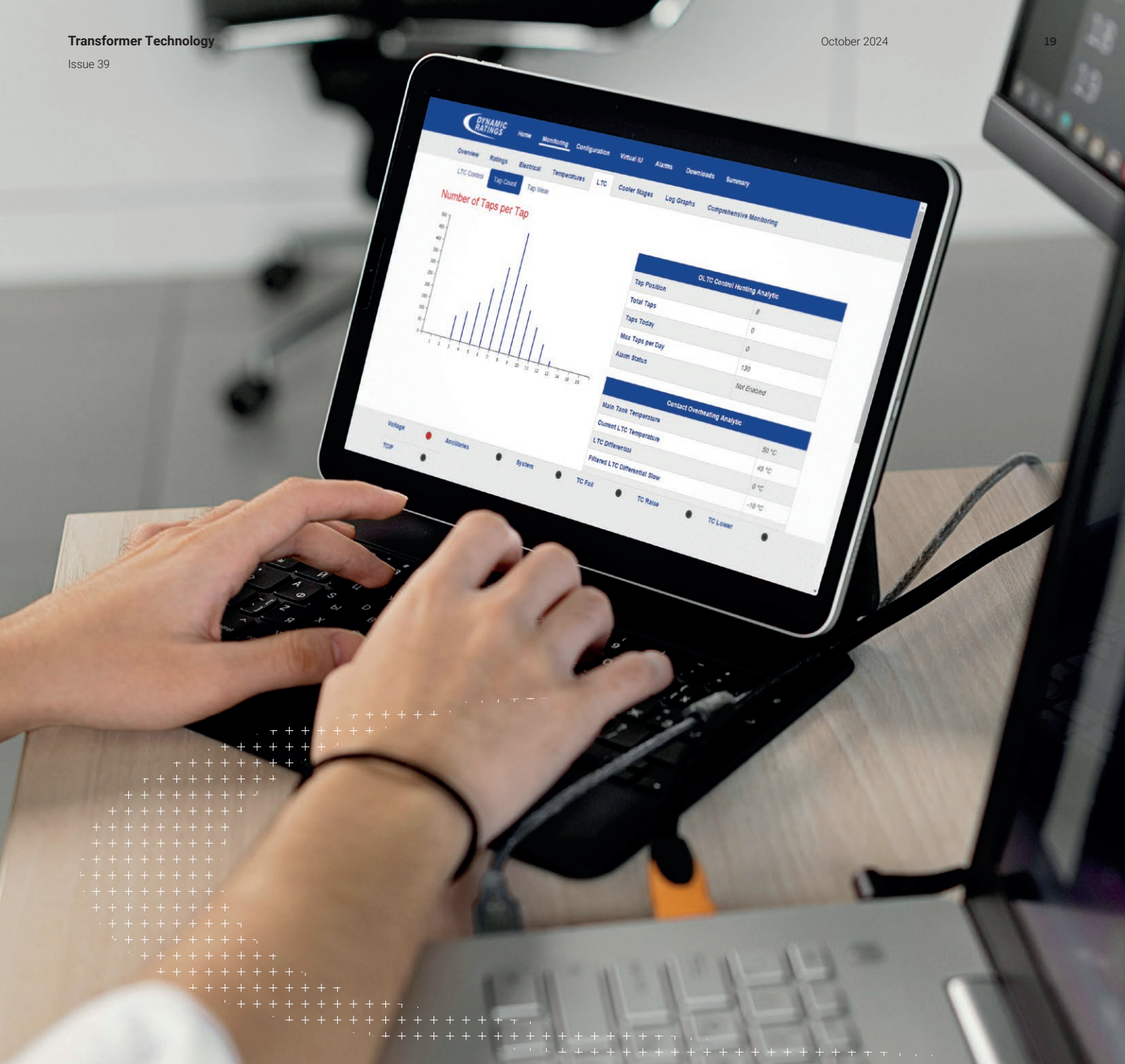
When combined, control functions are no longer performed blindly, and monitoring is no longer a passive activity. Since the control system is aware when a command has been issued, if it has access to the monitoring information, it can verify that the command issued was successfully completed.

Due to the number of moving parts, tap changer operation can be one of the more important functions to monitor on a transformer. Historically, the majority of the focus on an OLTC has been placed on the high voltage components (e.g., the tap changer contacts and insulating oil). While the importance of monitoring the high-voltage components cannot be underestimated (including monitoring of tap changer controls and drive mechanism), proper online condition monitoring for an OLTC should include DGA testing.

Dissolved gas analysis focuses on the levels of the individual gases generated during an operation as well as the ratios at which these gases are present in the insulating fluid. The prevalence of certain gases or related gassing patterns can indicate the condition of the tap changer's internal components and dielectric medium.

Dissolved Gas Analysis (DGA) offers critical insights that are crucial for a complete diagnostic picture. DGA can detect issues in their incipient stages when they are difficult to detect with other testing methods.

Simply put, this diagnostic accuracy eclipses other diagnostic tools and requires fewer resources than other offline methods such as visual inspections, thermal imaging, and acoustic analysis. DGA offers critical insights that are crucial for a complete diagnostic picture. DGA can detect issues in their incipient stages when they are difficult to detect with other testing methods.



Part 1:
Monitoring Motor Energy

Monitoring motor energy of tap changers is accomplished by recording the power a motor consumes as the tap changer passes through each tap. Tap changers usually have a 16-tap raise and a 16-tap lower.

As the motor changes the moving contacts between these, abnormal contact wear or alignment can occur, causing a variance in the amount of power consumed when compared to that of a tap that is in prime condition. Motor monitoring can also be effective for detecting problems with the tap changer's linkage.

While non-DGA methods can provide a limited assessment of contact condition without performing a visual inspection, complementing them with a DGA can be more effective than monitoring of motor energy, monitoring the temperature differential between the OLTC and main tank, and even infrared camera inspections alone.

Photo: Pexels, Dynamics Ratings

Photo: Dynamic

Part 2: Key Gas DGA (Hydrogen Only)

Hydrogen or key gas monitoring is using a hydrogen sensor to detect abnormal conditions occurring within the transformer, which is particularly effective as hydrogen is both the first gas generated when an abnormal condition occurs and also the only gas which is consistently generated as thermal conditions increase.

The levels of the other combustible gases being generated evolve as thermal energy is increased. For example, hydrogen and methane are generated at approximately the same thermal level but methane converts into ethane as the joules of energy expended begin to increase. As the thermal conditions continue to increase, that ethane is converted to ethylene and finally acetylene at approximately 700℃. This thermal progression and hydrogen's generation throughout make hydrogen monitoring the most practical, cost-effective solution for detecting abnormal operating conditions within the transformer.

Performing Dissolved Gas Analysis (DGA) on On-Load Tap Changers is essential for several reasons, primarily to ensure operational reliability and optimize maintenance practices.

Regular DGA testing is a proactive approach that ensures the long-term health and efficient operation of OLTCs, contributing to the overall reliability and safety of the electrical grid.

Part 3: Multi-gas DGA

Multi-gas DGA is a monitor capable of measuring diagnostic gases saturated in oil in the ppm range, making for more precise measurements. These monitors are available in the following:

- Five-gas: hydrogen, methane, ethane, ethylene, and acetylene.
- Seven-gas: carbon monoxide, carbon dioxide, hydrogen, methane, ethane, ethylene, and acetylene.
- Nine-gas: oxygen, nitrogen, carbon monoxide, carbon dioxide, hydrogen, methane, ethane, ethylene, and acetylene.

Hydrogen, methane, ethane and acetylene are deemed to be the combustible gases most crucial for thermal diagnostics of a transformer. (Carbon monoxide is also included in the combustible gas but is not related to a thermal value due to fault condition.) These gases provide an indication of the severity of a thermal defect due to the approximate thermal energy temperature at which they are produced.

H2:CH4~150℃
C2H6~250℃
C2H4~350℃
C2H2~700℃

As previously stated, the ratios of these gases are a reliable diagnostic tool for determining the nature of the defect.

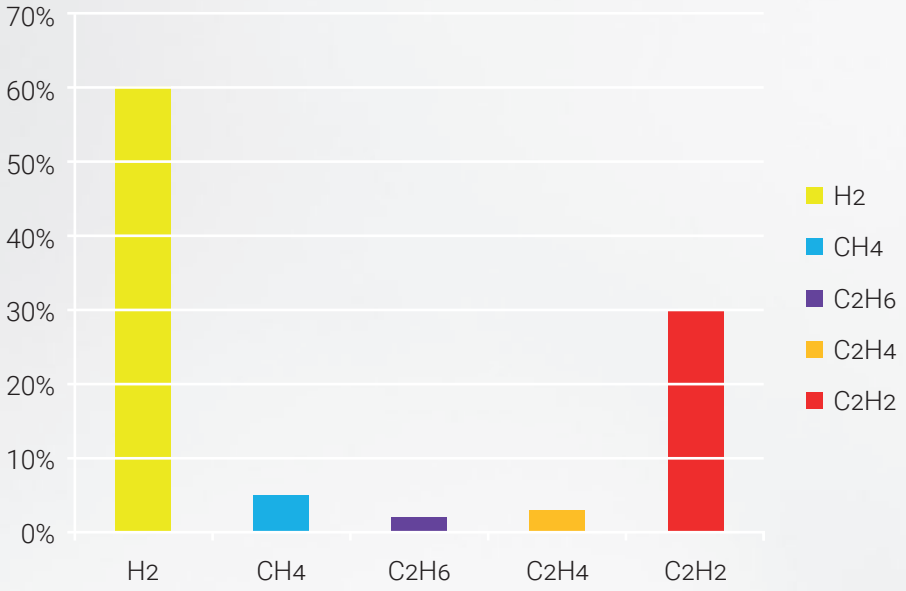
Hydrogen-Dominant

Partial discharge: this dominant hydrogen reading can also be related to stray gassing, core saturation due to excessive harmonics, higher than normal ambient, and load. To make an accurate diagnosis of which of these conditions are present, load and temperature readings need to be taken into consideration.

Also, examining which of the other combustible gases are being generated, and how they are evolving, helps determine if the condition is due to external factors or internal conditions. Hydrogen (which is accompanied by methane, that over time starts to convert to ethane or ethylene) is a solid indicator that an internal condition is becoming more severe and needs to be addressed.

Ethylene-Dominant

This is an indicator that a T2 or T3 level fault is present. Severity is



dependent on ppm values of ethylene being generated as well as levels of ethane and acetylene.

Carbon Oxides: Carbon monoxide and carbon dioxide are the carbon gases in this case. The ratio of these gases indicates the effect the abnormality has on the solid insulation system.

Nitrogen/Oxygen

These are atmospheric gases, which are a good indicator of the integrity of the transformer tank. Nitrogen is the expected dominant gas as it is inert and often used to provide a blanket of positive pressure for transformers that are not conservator tank designed. The presence of excessive oxygen is also detrimental as this can lead to excessive acid levels, which expedites the breakdown of both the solid and liquid insulation systems.

Multi-gas monitoring requires that oil be circulated through the monitor to ensure that a fresh sample is being measured. This is required for the monitor to provide a DGA measurement that is representative of the transformer's bulk oil.

Contact Condition

When it comes to identifying the contact condition of the OLTC, DGA sample analysis is the most accurate method of assessment.

This is achieved by observing the ratios at which combustible gases are present. For an accurate analysis, one must first recognize the gas ratios associated with a good arcing signature. In a sealed tap changer that is in good condition and functioning properly, the following ratios would be expected:

Hydrogen/Acetylene~ 2:1
Acetylene/Ethylene~/>10:1
Methane/Ethane~3:1

DGA analysis can also be used to diagnose faulty OLTC conditions in their incipient stages, allowing for costly failures to be avoided, making for better scheduling of labor-intensive internal inspections.

Arcing Signature

Just as these ratios are a good indicator of a healthy tap changer, DGA analysis can also be used to diagnose faulty OLTC conditions in their incipient stages, allowing for costly failures to be avoided, making for better scheduling of labor-intensive internal inspections.

For example, a DGA sample from a healthy OLTC would present a much different signature than one that was experiencing excessive contact wear. One of the best means of determining this excessive wear condition is using the Stenestam's ratio, as follows:

$CH_4+C_2H_4+C_2H_6/C_2H_2$

<0.5 no overheating

=>0.5-5.0 resample - the higher the initial number or if found to be increasing on resamples, sampling rate should be increased

>5.0 active overheating – active overheating is present, and an internal inspection should be scheduled

Another method for analyzing these samples is to track changes in the ratios when compared to baseline samples. If ethane is growing to become dominant over methane and starts to convert into ethylene, this is a solid indicator of incipient contact overheating.

An understanding of OLTC design is also necessary to make an accurate assessment of these samples. For instance, a free-breathing tap changer will allow hydrogen to rapidly escape to the atmosphere due to hydrogen's low solubility rate and molecular structure. Therefore, samples taken

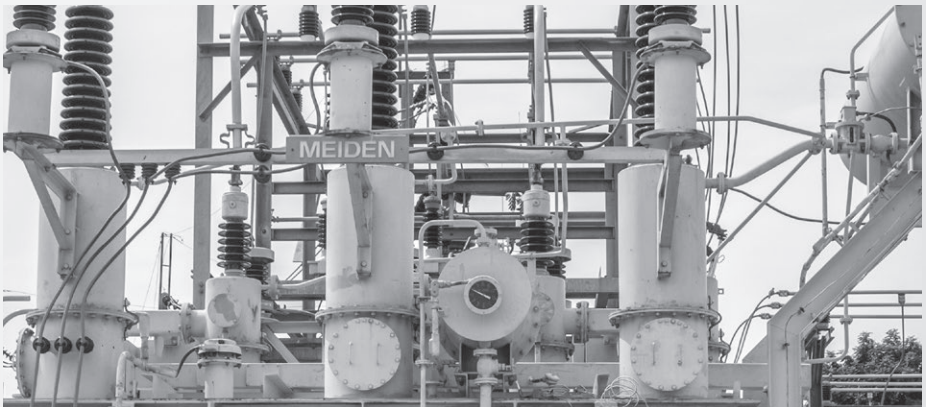


Photo: Dynamics Ratings

from these free-breathing designs will have lower hydrogen values than those of sealed tap changers.

Another reliable indicator of a free-breathing tap changer is the nitrogen-to-oxygen ratio, which is expected to be ~70% to 30%, or closely representative of the atmosphere. However, if these conditions are present in a sealed tap changer, it is a sound indication that a leak has developed.

Vacuum OLTCs

Over the course of the last three decades, Vacuum OLTC technology has become the predominant switching technology in the areas of medium-voltage substations and high- capacity power contactors, replacing oil- and SF6-based technologies. Today, more than 60% of the demand for circuit breakers in the medium power voltage segment worldwide is covered by vacuum-type circuit breakers.

Since all the arcing occurs in a vacuum bottle isolated from insulating oil, more operations are possible overall.

These operations can be monitored with hydrogen, as there should not be any gassing in the oil since arcing occurs in the vacuum bottles. In these vacuum tap changers, the presence of any combustible gases would indicate that one of the bottles has failed. For arcing in oil tap changers, hydrogen-only monitoring would not provide much value, as the combustible gases are needed to access contact condition. Essentially, hydrogen and acetylene should be the dominant gases. If ethylene becomes dominant, it indicates contact overheating.

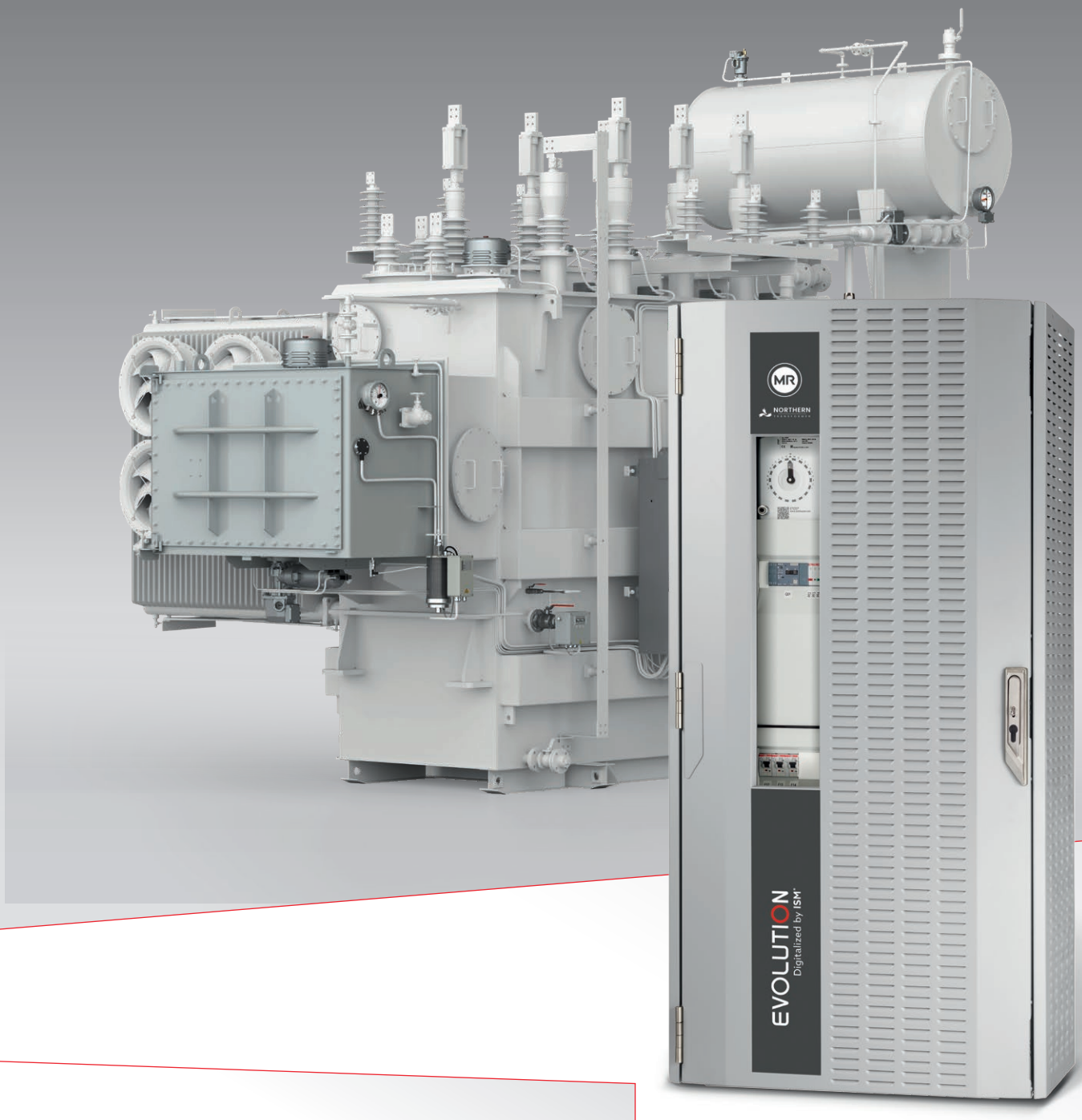
As all arcing for this type of OLTC occurs within a vacuum bottle, the presence of combustible gas in the DGA samples is an indication of vacuum bottle failure.

If a sudden increase in combustible gases occurs during any vacuum OLTC inspection, repairs should be scheduled immediately in order to avoid overall transformer failure.

Concluding Thoughts

Fully functioning online condition monitoring for an OLTC should strongly consider DGA testing, be it Key Gas DGA or Multi-Gas DGA.

Power transformers equipped with On-Load Tap-Changers have been the main components of electrical networks and industrial applications for nearly 90 years. DGA testing offers internal insights that are crucial for a full diagnostic picture, as DGA can detect issues that other methods might miss.



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NORTHERN TRANSFORMER'S EVOLUTION

THE DIGITAL SOLUTION FOR POWER TRANSFORMERS

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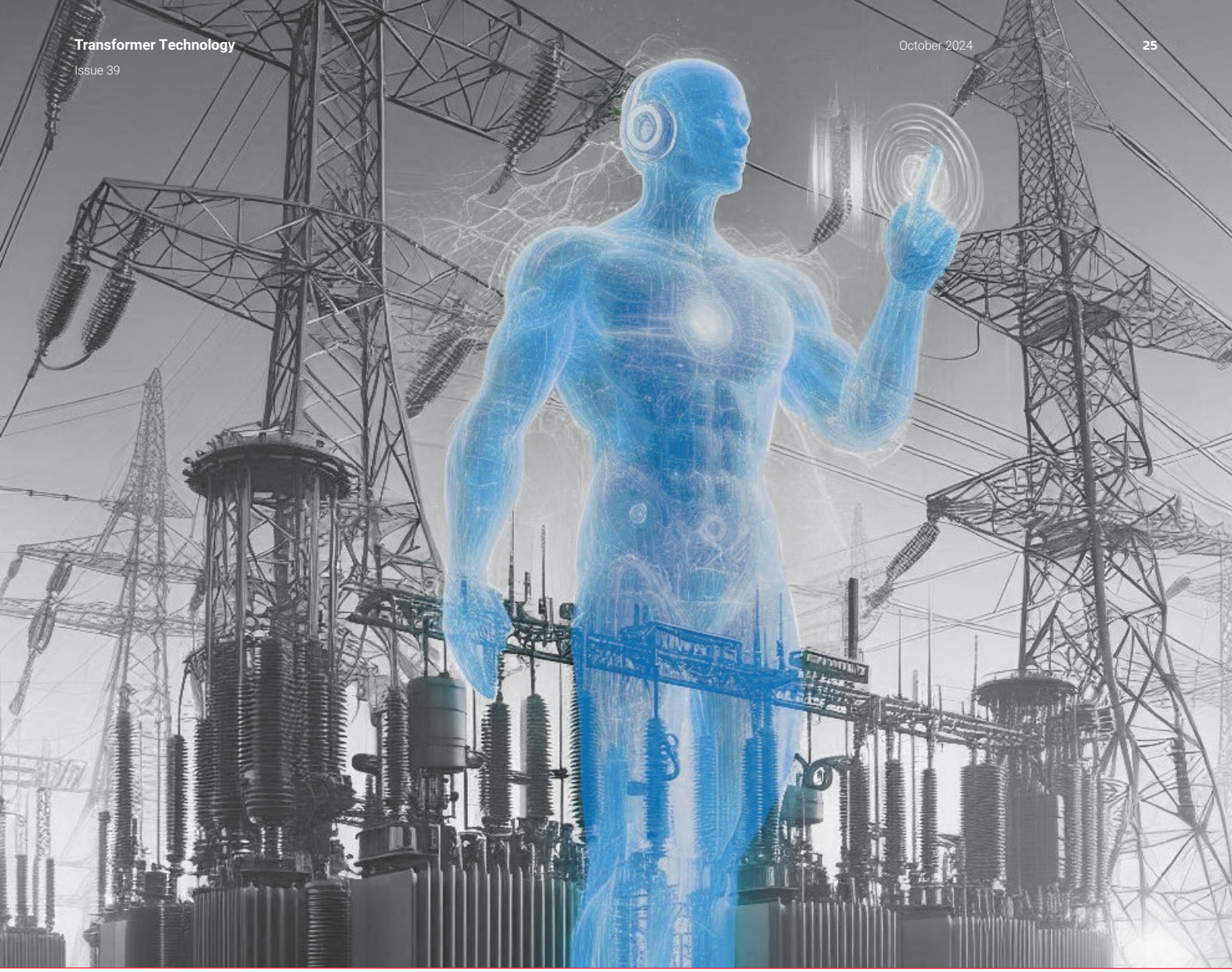

Alan Ross

I'm Alan Ross, the managing editor of APC Media and host of this interview with, Oktay Akkas, who is with MR, Maschinenfabrik Reinhausen, and Alexei Miecznikowski, the CEO, President, and a board member of Northern Transformer. We are talking about transformation, because the topic we're going to address is the whole area of digitalization and the collaborative work between MR and Northern Transformer. Oktay, give a little bit of a background about your career, how you got into the power industry, and what you're doing right now with MR.

Oktay Akkas

Thank you, Alan. I started my engineering career in 2007 with MR, as a testing field engineer. At that time, I was with the motor drive units testing team. Afterwards, I had the responsibility in Europe and switched to the automation system, handling the secondary equipment, and was responsible for projects in Europe for several years, until I changed to business development, to the business unit automation where I recognized that this is a challenging responsibility, including market development, business development and some sales activities. Today I am a business developer working with transformer manufacturers in Europe, and now also in North America.

Alan Ross

Thank you Oktay. Alexei, share with us how you got into this industry and why?

Alexei Miecznikowski

Thanks, Alan. I also have an engineering background. I studied engineering science and started in the electronics industry which is perhaps a good segue into our discussion later. I spent 20 years at Celestica, a spinoff of IBM.

Started in engineering, performed various roles in R&D, corporate development, sales, and was exposed to many different kinds of clients, some in highly regulated fields and others in consumer electronics. It was an amazing training ground. Just the diversity of the things we worked on.

We worked all over the world, with lights-out automation, high-mix-low-volume, very sophisticated systems. It was also a lot of travel. Your phone never turned off because everyone was in a different time zone. I was exposed to the energy industry while I was there, and an opportunity came up to help build this company to transform it, as you said, to its next level. Here was an opportunity to work at home with a facility here, with a whole supply chain here, with clients that are here. I thought, what an interesting opportunity, so I took it. That was eight years ago.

Alan Ross

What you're saying, it was your family that said, "we want you home more", and that you changed your entire career so that you could be home more. That's excellent. Having been here myself, I appreciate that.

Talk a little bit about Northern Transformer. You took it over in 2016. You were brought in to be transformative. I love the fact that you came from a good background to do what you're doing now. But talk a little bit about the company, the pedigree, where it's come from, where it is today.

Alexei Miecznikowski

It was founded in 1981 in Toronto by three veterans of the transformer industry. They built a company that had a very good reputation. It was the robust quality of the units, serving the local market, small utilities, commercial and industrial, up to about 44 KV. Those guys managed to build a company that had a great reputation. In fact, they really lived up to their motto, which was *"Quality you can count on from people you can talk to."*

Photo: Maschinenfabrik Reinhausen

Alan Ross
Is that still there today, that motto?

Alexei Miecznikowski
It is. That ease of doing business is something that's important to our team, and also making sure that we have the right people talking to clients directly and being able to address issues rapidly and clearly with the talent on the phone or today, in Teams meetings. That was a great base.

In 2012, it was acquired by a gentleman who is a very ambitious visionary. His vision was to build a company that would build power transformers here in North America. Of course, there are existing companies that do that, but they're generally part of large global companies. He saw an opportunity to take this small local company and build it up and set about investing in us.

We built a state-of-the-art, purpose-built facility, and we have been continuously investing since then. Our latest milestone is opening of the 240KV capability. We added vapor phase, testing bay with higher capabilities, vertical winding, all the requirements to do 240KV units. That's where we find ourselves today. But we're definitely thinking in a very long-term way about making those investments to allow us to provide the clients, the major utilities in North America, what they need from here at home.

If you don't have the right team and they don't have the right culture, you really won't get very far at all. We've spent a lot of time and effort and thought into how we maintain and increase the culture that we have. It's something that you work on every day.

Alan Ross
Let's discuss growth strategy. If you want to build a lasting growth strategy, you must do something different. You must be seen as the supplier of choice, correct? Talk a little bit about that and talk a little bit about the whole process of looking at a company that has an existing quality reputation moving to new markets, technologies or innovation. Speaking of MR for example, the load tap changer from Reinhausen, as a practitioner, I never had a problem with it because you can always rely on their quality, right? And yet, they are moving into other directions, services and innovation, all the while making sure to maintain that commitment to quality and customer support excellence. So it's a similar a situation. You have a quality company that has decided to expand, like MR, who is doing that with great success.

Now Northern Transformer is doing the same thing. Talk a little bit about your growth strategy.

Alexei Miecznikowski
That's a good question, Alan. For us, it's about the culture. This is a product and an industry that's very much about the people. If you don't have the right team and they don't have the right culture, you really won't get very far at all. We've spent a lot of time and effort and thought into how we maintain and increase the culture that we have. It's something that you work on every day. But I think we have a great culture, and it's brought us to where we are.

Now the question is how to keep instilling it as we grow. The industry is very reliant on people throughout the entire life cycle of what we do. You could be let down by anyone in the entire chain. It's so important to have a culture where everyone's there working together, backing each other up. The formal systems will get you so far, and they're helpful and they're required, but at the end of the day, if the team isn't motivated, if they don't have the right culture, it's still not going to work for you. That's a big part of how we got to where we are and how we're going to continue to grow in the future.

I'd say the other piece is finding the right clients. You need to find the clients that want to buy quality and who respect the fact that quality is not free, it requires an investment. That's a frank discussion you must have with them. If you can't come to an agreement to see eye to eye on that, then perhaps they're not the right client for you.

You need to find the clients that want to buy quality and who respect the fact that quality is not free, it requires an investment.

Alan Ross

That's an excellent approach to it because too many times we chase the dollar, and we get with somebody who commoditizes what we do. I have a philosophy that I borrowed from a CEO, friend of mine: Culture trumps strategy. In the long run, you can create strategies and plans, but if your culture isn't correct, as you said, it doesn't work. Kudos to you for selecting the right client.

It's like where MR is, right, Oktay? I'm going to switch to you next because we know MR very well at APC Media. You're a good client of ours. In a similar vein, we want to establish those relationships with the forward-looking companies. We're going to be talking about evolution, which, as I understand, is built on your ETOS platform. Talk a little bit about that and how, when you're working with Northern Transformer, why you picked them as a client.

Oktay Akkas

Well, let's say quality pays off at the end of the day. The point is that our ETOS solution is something new in the market that we combine with the drive functionality on the transformer. As soon as the tap changer is coming from Reinhausen, of course, the drive is combined to the tap changer and ETOS is included. ETOS itself is based on the ISM platform. The idea is to give the ISM platform to customers, a solution we call ETOS, and let them use this platform based on the ISM modules. It is branded and labeled by Northern Transformers as Evolution, for example.

We add more value on to the transformer, we centralize all the information, and then we digitalize this information coming from the transformer in real-time and forward it to the next level of control.

It is also possible for Northern to use the ISM platform and develop further applications on this platform. And that's the reason why, for example, Evolution can be different from standard ETOS.

Alan Ross

Excellent. The customization of the platform, as I became familiar with ETOS recently, is quite unique. I want to switch to you again, Alexei. You saw ETOS and said, “Okay, we are making a move to digitalization”, and you chose their customizable platform to be able to take to your clients. Talk about that decision and why you are collaborating with MR.

Alexei Miecznikowski

When I joined Northern, I immediately saw the need for digitalization. But I didn't see a path. I saw a lot of closed systems. I saw a lot of, let's say, niche solutions. But what I knew we needed was an open platform that we could build on. I also knew Northern wasn't the right company to go about trying to create that. It was not our skill set. We're a transformer manufacturer. We have very deep skills, but they're not in that area. And it had to come from a company that understood the transformer market. It is a very niche and unusual market.

Those entrants who were proposing solutions but weren't from this industry were problematic for me. Sure enough, one day, I got the call from MR where they took me through the proposition. I got it immediately. I also knew from our previous dealings with MR that like us, they have a vision. They invest for the long term, and they really understand us and our clients. When I saw that, then I started to explore what they had put together and I could see it was an open platform.

Photo: Maschinenfabrik Reinhausen

It was a platform that allows clients to adopt it now but add functionality in the future. It was a platform that allows clients to preserve what they already have, which for many utilities is a major challenge, mesh it together and find a path forward. And it delivers cost efficiencies.

Everyone benefits. It's not a new large expense. It's something that allows you to take advantage of what's already being shipped with every transformer and layer these extra capabilities on top. When we looked all that, and then we said, "Well, it's MRs, and they've done the work on making sure it's a robust quality platform", it was a pretty easy decision, actually, in the end.

Alan Ross

This is part of the word "interoperability". The utility industry is dealing with a rapidly changing digital platform. They have different requirements today than they had maybe a decade ago. Talk about how you discuss Evolution with a customer. Treat me like I'm a utility customer buying your transformer. Why should that even matter?

Alexei Miecznikowski

It's a long process with the utility because they're not starting from zero. They've already got an incumbent solution. What you really need to do is to take your time and help them understand first their incumbent solution, what it really is and how it can be enhanced, made better, more productive, lower cost, by working together with the Evolution system. Really, that's why we called it Evolution. It's not a one step, it's a slowly evolving approach to monitoring, and it allows you to get to where you want to go in the future.

Frankly, I think it's inevitable. It's going to happen, much the way evolution is. Now, it doesn't happen all at once, and some will move faster than others, and that's okay. Some have already invested more in the platforms that they already have. But at the end of the day, the logic is there. I've seen from my career in electronics, open systems, over time, in pretty much every case, have won out over the closed systems. Sometimes it takes time, but you'll get there eventually.

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Alan Ross

Excellent. To do what you've done together, it requires one keyword, collaboration. You must work together to collaborate, to take the platform, ETOS, and make it your platform Evolution; then it requires collaboration with the customer, which is another requirement. Talk a little bit about that whole concept of collaboration. Start with you, Oktay. How did it start with Northern Transformer?

Oktay Akkas

When we had the first presentation, as an online meeting. Before we started with the presentation, Alexei was just explaining his expectation. After several minutes, it was clear he mentioned all the points on our slides, on our presentation that we had prepared for this meeting. We had the strategic points, optimization, cost efficiency, differentiation in the market, everything that he mentioned all before having seen our presentation.

Then we just shared our slides, and Alexei said, "that was exactly what I was waiting for". Our team said, "Oktay, jump on the plane and go to Canada". We had a kick-off meeting there, signed the contract, and since then, the cooperation is ongoing. There will be a workshop in the next few weeks in Canada at Northern Transformer.

We will do process optimization, training on the product itself, we will have customer visits at Northern Transformers where we can present MR and Northern Transformer together. This is, I think, the difference.

It is not only customer and supplier relationship, but also a collaboration, hand in hand. We back up each other on this point. We try to support each other, and that is on a trust level, a real cooperation.

It is not only customer and supplier relationship, but also a collaboration, hand in hand. We back up each other on this point. We try to support each other, and that is on a trust level, a real cooperation.

Alan Ross
So, Alexei, he made your job a lot easier because you were sold before you were sold. Talk a little bit about your end of collaboration.

Alexei Miecznikowski
I mentioned before, Alan, I knew this had to happen, but I wasn't sure where it was going to come from. Over the years, I'd seen various proposals, and none of them made me comfortable that it was the right platform to move forward with. None of them had addressed them all the attributes we were looking for.

Then, Oktay and his team presented something that addressed all the points we were looking for. So it was a very easy decision, and the hard part now is now mobilizing the whole team on both sides. But it is also the fun part. Our marketing teams are working together. This is something new for us, but it's great.

We're also training the production team. We're training the engineering team. There's a lot. They have a lot of questions, as you can imagine, because they know that they're also talking to the clients as well. They really need to understand it well. It's been going great. The support has been fantastic. You always want it to go as fast as possible, but these things take time to do properly.

We're taking that time to invest and get it right up front. I'm delighted by this initiative, and it's one of the smoothest ones that I've experienced.

Alan Ross
Excellent. Gentlemen, congratulations, because I do think what Evolution and ETOS, what you're working together on does set a new standard. What I really like about this is you still have quality you can count on by people you can talk to from both companies. Thank you both, gentlemen.

Alexei Miecznikowski
Thank you, Alan.

Oktay Akkas
Thank you, Alan.

Oktay Akkas is an engineer in the field of energy transmission with over 17 years of technical and managerial experience. At the beginning of his career, he started at Maschinenfabrik Reinhausen as testing engineer for OLTC motor drive units and managed afterwards the sales & service responsibility of MR's Automation & Control products in Europe. Beside his sales activity he also had influence on the R&D with his experience for secondary equipment in electric power grids. Currently he is responsible for the business development of OEM business at the business unit AUTOMATION and successfully driving the cooperation business with transformer manufacturers in Europe and North-America. Oktay graduated with honours Bachelor of Industrial Engineering at the private University of Diploma (Germany).

Alexei Miecznikowski is CEO, Member of the Board, joined Northern Transformer Corporation as Chief Executive Officer and Member of the Board in 2016, to lead the company through its transformation to become a leading power transformer company. He has global business experience after 21 years at Celestica Inc where he led the development of business lines with revenues exceeding $500M including energy, healthcare, communications and automation. His experience spans sales, business development, government relations, research and development and global supply chain/operations. Alexei graduated with honours Bachelor of Engineering Science at the University of Toronto. Alexei also serves as a Board Member of the Electro-Federation of Canada, the voice of Canada's electrical industry.

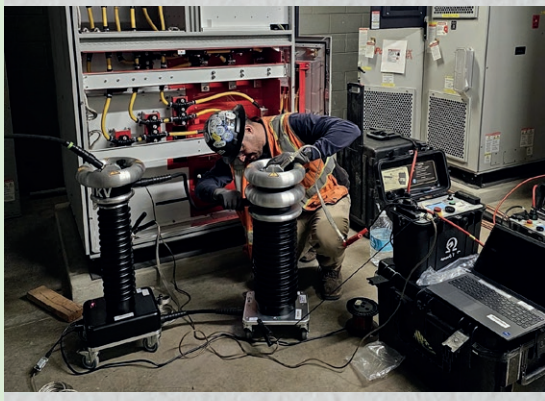
COMPANY SPOTLIGHT RESA POWER

“Leading the Way in Reliable and Safe Power Solutions

Reliable and Safe. The Power of Us.

RESA POWER™
Reliable and Safe. The Power of Us.

Photo: Resa Power



In today's rapidly evolving power industry, reliability, safety, and expertise are non-negotiable. One company that exemplifies these values is **RESA POWER** - a premier provider of electrical power services across the U.S. and Canada. With over 50 locations nationwide, RESA Power has established itself as a trusted partner for **data centers, utilities, industrial facilities, renewable energy providers** and other vertical markets, offering top-tier power system solutions tailored to meet the diverse needs of these critical sectors.

The Power of Expertise and Innovation

At the heart of RESA Power's success is its dedication to both **safety and performance**. Offering a broad array of services under its core pillars - Field Services, Power Systems, Transformer Solutions, and Specialty Distribution - the company's versatility is unmatched. Whether it's preventive maintenance, rapid emergency response, or cutting-edge transformer assessments, RESA Power provides comprehensive solutions that keep businesses powered and protected.

Transformer Solutions: Empowering the Backbone of Power Systems

RESA Power's **Transformer Solutions** division is designed to enhance the performance and lifespan of transformers, the backbone of modern electrical grids. The company's field services go beyond basic repair. They offer **turnkey installations, regasketing, reconditioning**, and **thorough testing** to ensure transformers operate at their peak for years to come.

For those needing **engineering expertise**, RESA Power offers in-depth **fleet assessments** and modernization solutions that not only prevent breakdowns but also improve overall system efficiency. Meanwhile, their **repair centers** specialize in **remanufacturing**, ensuring transformers are returned to service as good as new.

In addition to equipment, RESA Power's **Fluid Lab Services** offer essential testing and analysis, which are key to maintaining transformer health. The company's **Transformer Assessment Portal (TAP)** and **Long-term Service Agreements (LTSA)** ensure continuous monitoring, providing customers peace of mind that their equipment is always running optimally.

Comprehensive Power System Services

Beyond transformers, RESA Power provides a full suite of **power system services** designed to keep electrical systems running smoothly. Their offerings include **electrical testing and diagnostics**, **preventive maintenance**, and **emergency repair** services. What truly sets them apart is their **24/7 emergency response teams**, ready to tackle any power crisis and minimize downtime.

RESA Power also stands out for its ability to offer **innovative solutions** that enable the delivery of power systems with shorter lead times than what is typically available in the market. This competitive advantage allows clients to meet project timelines more efficiently without compromising on quality.

Additionally, RESA Power specializes in **custom LV switchboard manufacturing** (UL 891 certified), as well as **custom design**, **reconditioning**, **replacement**, and **demolition services**, providing tailored solutions for clients with unique project needs.

Specialty Distribution and Custom Solutions

RESA Power's **Specialty Distribution Services** round out their comprehensive portfolio. By offering a wide range of **electrical components** and **temporary power solutions**, the company ensures customers have access to the right tools and equipment, when they need them. Their ability to **customize electrical systems** makes them an invaluable partner for complex projects.

National Reach, Local Expertise

With **over 50 locations** and a team of highly skilled technicians, RESA Power delivers **local expertise with a national network**. Whether it's a complex power system upgrade or a rapid-response emergency service, RESA Power has the resources and local insight to ensure every project is executed with precision and speed. Their extensive in-house inventory allows them to offer **quick turnaround times**, ensuring critical components are always within reach.

Why RESA Power?

What makes RESA Power stand out is its dedication to providing top-tier services, backed by a team that prioritizes **safety and quality**. With a nationwide presence, RESA Power offers the advantage of localized service combined with the resources of a national leader.

For industries in need of comprehensive solutions, from transformer reconditioning to power system maintenance, RESA Power is the **trusted partner**. With a broad range of services and deep expertise, the company is well-equipped to meet the evolving power needs of businesses today and into the future.

As the company grows, its focus remains on delivering exceptional service, ensuring safety and reliability, and making a positive impact in the communities it serves - driven by the motto **Reliable and Safe. This is the Power of Us**.

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EVOLUTION OF GLOBAL POWER GRIDS AND CHANGING NEEDS FOR TRANSFORMER BUSHINGS

YASH HIGHVOLTAGE

Photo: YASH Highvoltage

Introduction

With the evolving **dynamics** of global **power grids** and the rising demand of electricity driven by factors such as **population growth, rapid developments of infrastructure such as railways/data-centers/EV charging stations, upgradation of ageing power grids** and the integration of **renewable energy generation** to support **sustainability & carbon neutrality**, the **need for transformers and transformer bushings** has also transformed significantly. These changes require innovations in design, performance, and reliability to meet the growing and more complex demands of modern power systems.

In this article, we briefly describe the factors behind the advancing global power demand, and how Yash Highvoltage Ltd. adapts to catering the progressive needs of the industry. Yash Highvoltage Ltd. is a manufacturer of niche, condenser graded transformer bushings with supplies to over 60 countries. With a further rapidly expanding supply base globally, YASH envisions to playing a vital role in enhancing the world's power generation and transmission landscape.

Factors driving the power demand and evolution of Global Power Grids

Renewable energy and sustainability

As the **global population** continues to **rise**, the **demand for power** and **energy** has **surged** at an unprecedented rate. This growing need is fuelled by the **increasing reliance on electricity** for daily life, infrastructure, and emerging technologies.

In **1990**, the per capita primary energy consumption was recorded at **17,972.46 kWh/person** globally, which has **increased** and reached **21,393.7kWh/person** globally in **2023**. This clearly indicates that energy needs have expanded beyond traditional usage such as heating, cooling, and lighting over the past two decades.

Charging electric vehicles, which are becoming more prevalent in efforts to reduce carbon emissions, places additional strain on power grids. Similarly, railway systems that are shifting from fossil fuels to electric traction, require substantial energy to operate efficiently. Moreover, as the global economic landscapes are shifting towards **net-zero emissions & carbon neutrality**, demand for generating electricity from **renewable energy** sources like solar, wind, hydro and nuclear are gaining precedence and preference. Most renewable energy generation is cyclic and variable, owing to it is dependence on natural sources such as wind, sunlight or waves in the ocean for example. Devices such as Static VAR compensators (SVCs), popularly known as STATCOMS are seeing increasing significance and usage across global Powergrids for reactive power compensation, keeping the grid stable against varying loads and improving the power quality. STATCOMs utilize Coupling Power Transformers on MV Side (for connection to Grid) typically requiring 36kV ~ 72kV Transformer Bushings with Current Rating between 5000A & 10,000A.

52kV 6600A 300 BCT High current bushing for POWERGRID STATCOM projects

Along with these factors, innovations in the power sector have further boosted efforts to generate clean energy, a notable one being the production and usage of **green hydrogen**.

Green hydrogen is collected through **electrolysis**, a process that uses electricity generated from renewable sources—to split water (H_2O) into hydrogen (H_2) and oxygen (O_2). A significant amount of power is required for carrying out electrolysis at large scale, requiring specialized Power transformers at the input source, calling for High current bushings typically ranging between 5000 to 7000A currents at the MV side of those transformers.

At YASH, we have successfully developed and have supplied several MV Bushings for High Current Applications with end use in STATCOM coupling transformers as well as Transformers for use in Green Hydrogen production.

India - towards a sustainable future

With a focus on carbon neutrality, developing countries such as India have committed to reducing carbon emissions by 50% by 2030 and achieving net zero by 2070. These government initiatives are driving the demand for renewable energy.

A prime example of this is the Bhadla Solar Power Plant in the Northwestern part of the country, spread over an area of 56 square kilometres and a total installed capacity of 2,245 megawatts (MW), making it the largest solar power plant in the world as of April 2024.

In addition to carbon neutrality, the expansion of Dedicated Freight Corridors (DFCs), highways, and high-speed rail (bullet train) and inter-city metro rail projects is increasing energy demand drastically.

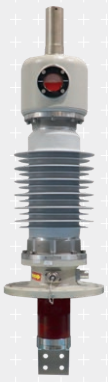
For instance, **India's Dedicated Freight Corridors (DFCs)** are electrified rail projects designed to enhance the efficiency of freight transportation. These corridors significantly increase **energy consumption** due to the shift from diesel to electric trains. **Traction transformers**, installed at substations, convert grid power to the voltage needed to run the trains.

Yash's range of OIP Transformer bushings rated 52kV up to 245kV have been used in across several railway and traction projects within India as well as internationally, for instance for the Italian Railways (RFI).

Natural disaster and extreme environment

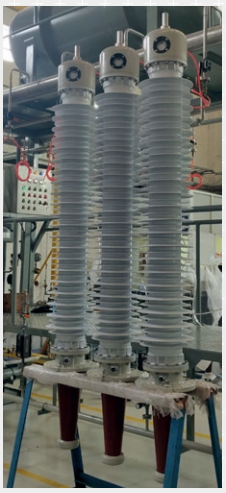
Natural calamities such as hurricanes, earthquakes and floods require robust power infrastructure which can sustain extreme conditions. Utilities in seismic zones are increasingly opting for **transformer bushings with Silicone/ Composite/Polymer insulators** over traditional porcelain insulators to minimize damage during earthquakes and enhance overall safety and reliability.

OIP bushings with Polymer insulators



36kV 3150A 0CT

72.5kV 800A 300CT



170kV 800A 300BCT

YASH with its state-of-the-art infrastructure and R&D centre has developed, type tested, and eventually manufactured and supplied hundreds of OIP bushings with Silicone/Composite/Polymer insulator to various customers globally. One of the noteworthy products under execution include 245kV OIP bushing with polymer insulator for a renown transformer customer in Turkey, for end use in the Turkish grid.

Having successfully engineered and supplied **OIP (Oil Impregnated Paper) bushings** for power grids located in regions with extremely low temperatures, capable of withstanding conditions as harsh as **-50°C** and **-40°C**, YASH has established a niche as an innovative solution provider. For such bushings, **special insulating oil with low pour point** and **O-Rings / Gaskets** suitable for **minus temperatures** are used.

Photo: YASH Highvoltage

Exported special 145kV 1250A 600BCT OIP bushing suitable for -45°C Temperature

Transformer Bushings for Global Markets

The world of transformer bushings is complex, with several countries having their own standard requirements. These variations encompass dimensions, technical specifications, voltage ratings, and construction types. Rather than view these differences as challenges, YASH has embraced them as opportunities for innovation.

While the company produces a robust standard range of transformer bushings to meet IEC 60137, its true strength lies in engineering customized solutions tailored to the specific needs of diverse international markets. This commitment to quality and innovation ensures compliance with global standards while addressing the unique demands of power utilities in various regions.

Tailored Solutions for European Utilities

For instance, to meet the stringent requirements of European power utilities, Yash Highvoltage developed a complete range of **Shorter Oil End Length Bushings**. These bushings meet the requirements as per the CENELEC/EN standards, ensuring they are specifically suited to the unique challenges of the European grid. Featuring a specially designed Oil End Insulator with an embedded electrode, these bushings are engineered to perform reliably under higher radial and axial stresses, with exact dimensional interchangeability to existing reputed European makes of bushings. This enables transformer designers to seamlessly utilize the YASH short oil end bushing solution without any change in transformer design or engineering. This bushing range is available upto 170kV as of today and will be expanded upto 245kV within a year.

72kV 800A Shorter Oil End Length Bushings Tailored for European Utilities

Meeting U.S. Standards

In addition to its offerings in Europe, Yash Highvoltage has worked towards building a reputation for its specialized transformer bushings, which are designed and type-tested **to meet IEEE C57.19.00/01 and C57.19.04 standards in the United States**. These standards encompass both high-voltage condenser bushings for power transmission and high-current bushings used in power generation. Our custom-built solutions are thoughtfully engineered to meet the specific conditions and ratings required by U.S. power systems, allowing for seamless integration and interchangeability with well-known global bushing manufacturers, while also ensuring reliable performance.

The Yash range of OIP condenser IEEE bushings spans from **15kV to 230kV** in rated voltage. We have had the opportunity to work with several transformer manufacturers in the U.S. and those exporting to the U.S. – to utilize our IEEE range of OIP condenser bushings. One notable example is our 34.5kV 8000A 534BCT high-current bushings, supplied to reputed transformer OEM Siemens India, for a project with LADWP in the U.S., and the bushings have been working satisfactorily for over 3 years.

A Landmark Achievement

In the realm of power generation, generator transformers (GSU's) play a pivotal role by stepping up generated voltage for transmission across extensive power grids. High current bushings are essential for safely transmitting large electrical currents carried by busducts between the power generator and the Generator step-up transformer. A notable milestone in YASH's journey was the recent manufacture and export of India's first 25,000A rated High Current bushing, supplied for a renown international hydropower plant.

Range of Bushings as per IEEE Standard

34.5kV 8000A 534BCT

25kV 1200A 534CT

34.5kV 3000A 534CT

69kV 800A 550CT

138kV 800A 534CT

36kV 25,000A High Current Bushings developed for Hydropower Plant

To meet the increased demand for Transformer bushings globally, YASH have augmented their existing manufacturing facility to produce close to 12,000 OIP bushings annually. The facility addition is equipped with cutting-edge technology sourced from renowned manufacturers in Europe/USA and is well-positioned to cater customers with industry best lead times.

Electro-Magnetically Shielded EHV Test Laboratory
1500kVp Impulse Test Lab System
600kV HV Test System

SCADA Controlled Autoclave System

Photo: YASH Highvoltage

By continually addressing the unique challenges of global markets, Yash Highvoltage Ltd. not only enhances its product offerings but also plays a vital role in shaping the future of energy distribution worldwide. Through each tailored solution and technological advancement, we believe in transforming the energy landscape - **one transformer bushing at a time**.

PERSPECTIVES

Photo: Shutterstock

Sustainability in the High Voltage Power Industry - Who is going to help keep the lights on?

I have been involved in the HV Power Industry since I crossed the threshold of a small factory in the Province of Ontario which produced pole top distribution transformers in 1971. Fresh from secondary school, where at the time a 5-year program in Science Technology & Trades was offered, I applied for a job at this factory. I was hired that day as I knew how to 'lead a bead'.

Since that day, and thanks to the education I had in the basics of 'shop' work, as well as physics and chemistry - including how to set up and read meters, read drawings and use a slide rule for computations - I began what has turned out to be a long and progressive apprenticeship in this industry, which continues to this day.

I am not an engineer with formal training and license, but the knowledge that was shared with me by many supervisors, peers, managers and mentors in all aspects of life, has brought me to a point where I now look back with some satisfaction, but also a good deal of concern.

The concern is who will step in to fill the gap, as I, along with many others of my generation, reach a point in life where our collective knowledge will no longer be readily available to the younger people who decided to take up the roles we played.

The concern is who will step in to fill the gap, as I, along with many others of my generation, reach a point in life where our collective knowledge will no longer be readily available to the younger people who decided to take up the roles we played.

The past few years I have made it a point to share what I have learned from experiences in growing up through the ranks of the transformer industry and participating in the early stages of the application of online monitoring technologies on transformers. I have shared the knowledge gained from various forums, such as factory and field experience, observations, getting your hands dirty, and most importantly, ASKING QUESTIONS to those who have traveled this road before me.

Utilities that produce and deliver electrical energy have a vital role to play in developing the young talent that arrives at their door. Some but not all have taken it on with dedicated apprenticeship programs in their companies, others hire interns who, based on their aptitude, curiosity, and willingness to learn by experience and working with the veterans, discover different paths within this industry to develop a passion for their role in it. After all, much of what they learn from the veterans will not be found in a textbook.

Another avenue to learn is via participation in organizations such as IEEE, IEC, CIGRE and CIRED, where networking with like-minded people can lead to a lifetime of networking, and learning, with active participation in standards and guides development. I have found more than a few utilities and larger power users don't sponsor aspiring talent to participate, citing 'budget' and/or travel restrictions. In my mind this is a very short-sighted position to take, not to say disappointing to the individual who want to participate. Not only that, but the various working groups I have been in and continue to be involved with express the need for more involvement by the end users (in this case transformer users) in providing their input to these guides and standards.

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This avenue, wherein my past employers did support me in active participation in IEEE and CIGRE, as well as other industry-focused events, played a major role in my career. This led to writing papers and columns in trade journals, where in some cases we passed along our experiences and ideas with other co-authors, hopefully leaving a trail in print for others to follow.

If you have a curious mindset, carry on and build on it. My personal takeaway message is NEVER STOP ASKING QUESTIONS.

Producing webinars was another useful exercise that provided focus in the spoken word on specific topics of interest. These will live on. The feedback I have received from many people around the world who, at times, witnessed these live in the middle of their nighttime, has indicated to me that the effort was worthwhile.

People ask me *"What can I do to have a career like yours?"*

One answer is to develop a skillset that includes effective public speaking. This is a skill one can learn. Many, including myself at the beginning, were not comfortable getting up and speaking in front of a crowd on a topic they know inside out. Learning this skill will benefit you in a professional and personal sense for the rest of your life.

If you have a curious mindset, carry on and build on it. My personal takeaway message is NEVER STOP ASKING QUESTIONS.

Author:
Brian Sparling
Senior Transformer Technical Advisor
with Kinectrics Inc.

Brian Sparling, SLMIEE (a Senior Life Member of IEEE), is the Senior Transformer Technical Advisor with Kinectrics Inc. Brian has over 20 years of experience in the field of power and distribution transformers. For the past 30 years, he has been involved in all aspects of monitoring, diagnostics, and condition assessment of power transformers. He has authored and co-authored more than 34 technical papers on various topics dealing with monitoring and diagnostics of transformers. He has contributed to many guides and standards with the Canadian Electricity Association, IEEE Transformers Committee, and the Cigré A2 Transformers Committee.

Inside CIGRE Paris 2024: Industry Insights and Grid Innovation

In late August, I went to the biennial CIGRE conference in Paris France in my capacity as an Executive Advisor to APC Media to interview thought leaders who are working at the core of the global second age of electrification and energy transition. My goals were to better understand and report back to our readers current electric power industry challenges, trends, solutions, and what makes experts so passionate about CIGRE Paris. While I have been to Paris several times over the last couple decades, this time was special. Not only because my wife and I connected with a Paralympic athlete on the flight over, followed her progress at the games, experienced the city-wide Olympic celebrations in the evenings, but among the record-breaking 11,000 CIGRE participants, I am most grateful to have reconnected with so many long-time industry colleagues and engage and interview numerous industry leaders in a diversity of roles from C-suite to technical expert.

During the six-day event we scheduled interviews with sixteen thought leaders including C-Suite representatives, Peter Cunningham with Camlin Group, Dr. Bahadir Basdere with Trench Group, Holger Ketterer with SGB - Smit Group, and Stéphane Page with Condis. We also interviewed globally recognized technical experts in leadership roles including Jacco Smit with Tennet, Seamus Allan with Dynamic Ratings, and Diego Robalino and Niclas Wetterstrand with Megger. All the one-on-one interviews encompassed the similar questions requesting perspective on what the industry challenges and trends are, what solutions they are bringing to market, and what they are excited about here at CIGRE Paris 2024. Stéphane Page did a great job summarizing the current industry: "We are living in an unbelievable moment in our industry, investments in electrical infrastructure are just massive."

The topics ranged from switches, bushings, transformers, cable, protection, monitoring and test equipment. All our guests were seasoned industry veterans, and they all expressed an excitement about our industry's growth, the like they have never seen before. Seamus Allan noted that "One of the biggest challenges at moment is the knowledge gap that is emerging" and Holger Ketterer stated that with "One of biggest challenge in the near future is the need for skilled labor."

Some of the solutions our guests identified are the acceleration of standardization, better production planning through partnerships, monitoring to direct risk mitigation and reduce workforce knowledge requirement, investment in production, technology based technical services to replace knowledge gaps. In short: "Explore. The grid does not come to you. You need to go into the grid." (Jacco Smit)

This was my first time attending CIGRE so I had several surprising first impressions. In a word, the CIGRE conference is about relationships. Relationships that enable learning, problem solving and make business happen in the electric power industry. CIGRE does not produce standards, but the technical brochures created by study committees made up of delegates from countries around the world are often the industry golden standard for the basis of IEEE, IEC and other national standards. If you're familiar with the IEEE T&D Conference and tradeshow, this event is similar in scale, but I found it to be far more compact, accessible, and intimate. The two main amphitheaters are surrounded by a multilevel tradeshow and breakout rooms of various sizes. This means one can go from a commercial discussion in a vendor booth to a

Photo: Ben Lanz

panel session with hundreds of attendees or a technical committee session in a few steps. In my experience, paper "poster sessions" are generally poorly attended, but not at CIGRE. The poster session area was packed, and the energy and excitement were palpable. Each poster station with its large monitor screens and a presenter were well attended by multiple people. Even the papers selected for oral presentations in one of the amphitheaters were different than most conferences. They were grouped by topic, each contribution was only a few minutes, and questions were only taken after the presentations on a given topic were complete. This unusual process enabled over a thousand papers to be presented in poster or oral format covering the breadth of power system topics exposing the attendees to a buffet of new and thought provoking ideas. If CIGRE 2026 is not already in your business travel plans, I recommend you reconsider.

In a word, the CIGRE conference is about relationships. Relationships that enable learning, problem solving and make business happen in the electric power industry.

I hope you enjoy the interviews as much as I did and that you take away valuable insights that can positively impact our collective efforts to meet our society's goals to upgrade our grid, the cornerstone of our modern civilization. I would like to thank all our interviewees for their insights, APC Media production team, and my employer, Osmose Utility Services for their commitment to advancing thought leadership in our industry.

Author:
Ben Lanz
Executive Advisor, APC Media
Director, Solutions Consulting, Osmose

With over 30 years in the electric power and energy industry, **Ben Lanz** is responsible for Osmose (Osmose.com) technical outreach and education efforts and is the immediate past Chairman of the Board of the Power Delivery Intelligence Initiative (PDI2.org), a nonprofit dedicated to disseminating grid investment best practices. He is a senior member of IEEE PES and ICC, and a voting member of DEIS, IAS, ACP, CIGRE, SaRA & NETA. He has chaired IEEE technical committees associated with power system reliability, protection, and testing, has published over 100 papers, articles and technical conference contributions on the subjects of power system reliability, asset management, design, work practices, longevity and diagnostics, and is a regular guest speaker at numerous conferences and seminars.

Power Transformers Supply-Demand Dynamics - Should you still invest in new production capacity expansions?

Power transformers are the backbone of our electricity grids. However, today, despite being one of the most critical assets of the system, they are also one of the hardest to procure, with limited availability and long lead times. Today, a lead time of less than 30 months to source a power transformer is considered quick, compared to the 12-14 months it used to be a few years back. But how did we get here?

A big driver of this shortage is the increased demand for power transformers over the last few years. As the power grids are undergoing major transformation due to energy transition and grid modernization, power transformers are needed in larger quantities than ever before. In the next three years, around 4 TW of new generation capacity is expected to be added globally, driven by our increasing electricity needs and the shift towards renewable energy. Couple that with substantial investments by utilities in grid expansion, upgrade, and asset replacement to evacuate this power, and we are looking at an increasing long-term demand for power transformers. Research by PTR Inc. suggests that the demand for power transformers will grow annually at a rate of 6.3% between 2024-2027, going from 1.98 million MVA to 2.38 million MVAs within this period.

As the power grids are undergoing major transformation due to energy transition and grid modernization, power transformers are needed in larger quantities than ever before. In the next three years, around 4 TW of new generation capacity is expected to be added globally, driven by our increasing electricity needs and the shift towards renewable energy.

On the flip side of the coin, the situation of power transformers manufacturing and supply is a bit different. PTR's research indicates that the current global production capacity of power transformers OEMs is around 3.25 million MVAs. This is further expected to increase annually by 2.5% in the next three years between 2024-2027, considering several capacity expansion announcements by power transformers manufacturers around the world.

Contrary to what one might think without looking at the numbers, the production capacity is significantly higher than the demand for power transformers. However, this might be a misleading statement since the actual production from the factories still lags behind the demand by around 2%.

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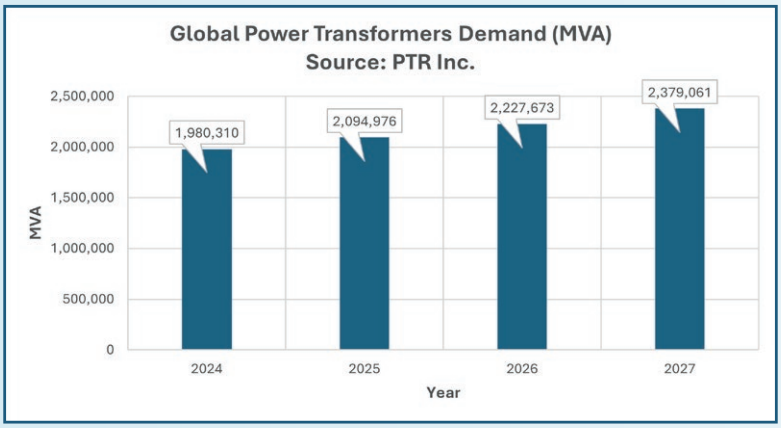

Figure 1.
Global Power Transformers Demand (MVA)

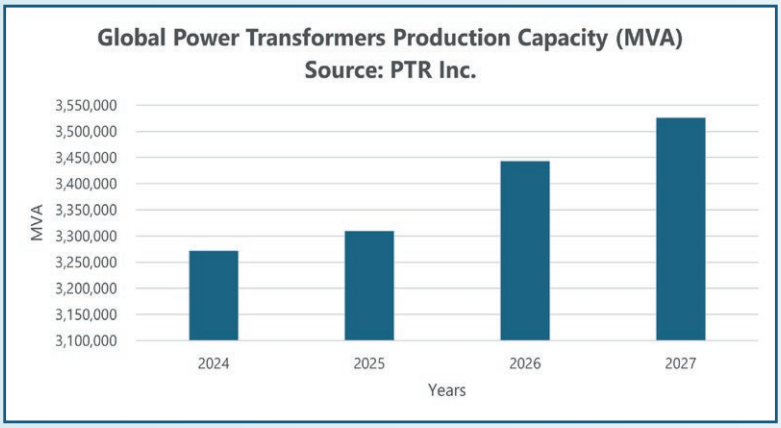

Figure 2.
Global Power Transformers Production Capacity (MVA)

Due to the complicated vendor approval and supply process, as well as logistical challenges, material and labor shortages, manufacturers in some parts of the world are not able to produce at 100% factory utilization and export power transformers to alleviate this supply gap. The trend that PTR expects will continue over the next 3 years at least.

Due to the complicated vendor approval and supply process, as well as logistical challenges, material and labor shortages, manufacturers in some parts of the world are not able to produce at 100% factory utilization and export power transformers to alleviate this supply gap.

The key to understanding this underutilization, despite the high demand, lies in understanding the regional supply-demand dynamics. During this research, PTR looked at the production capacity and demand dynamics in each region.

The key to understanding this underutilization, despite the high demand, lies in understanding the regional supply-demand dynamics.

Starting with **North America**, driven by the strategic shift towards higher renewable share in the energy mix and modernization of the aging grid infrastructure in the US, the region is one of the key demand hubs for power transformers. Between 2024-2027, the expected cumulative demand for power transformers in North America is 1,044,500 MVA. The region is also emerging as a crucial hub for investments in power transformers production capacity expansions. So far, various manufacturers have announced a total investment of USD 828.9 million in capacity expansions of which US alone accounts for USD 507 million (67%). This includes both greenfield factories, as well as capacity additions to existing factories. However, despite these investments, the region will stay a net importer of power transformers with the expected annual gap of around 100,000 MVAs per year between the demand and production within the region.

Another region that is a net importer of power transformers is the **Middle East and Africa**. With mega construction projects in the GCC region and growing renewable investments, the demand for power transformers is expected to grow significantly in the region at a CAGR of 7.3% per year between 2024-2027, totaling a cumulative 895,000 MVA over this period. From a supply perspective, the region has a high dependency on imported power transformers with around 90% of the power transformers being imported today.

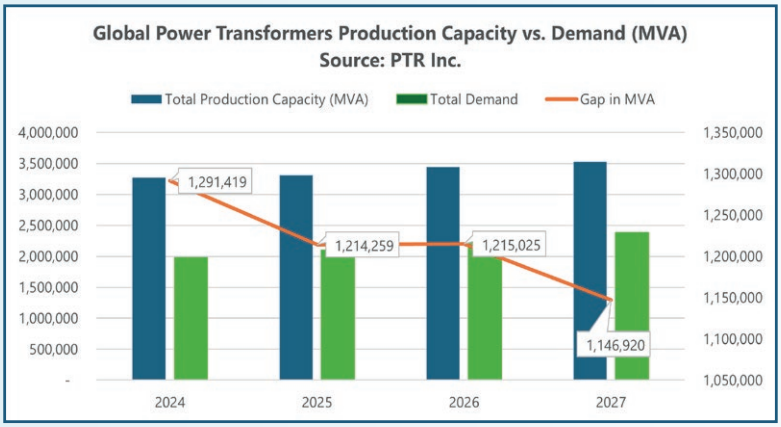

Figure 3.
Global Power Transformers Production Capacity vs. Demand (MVA)

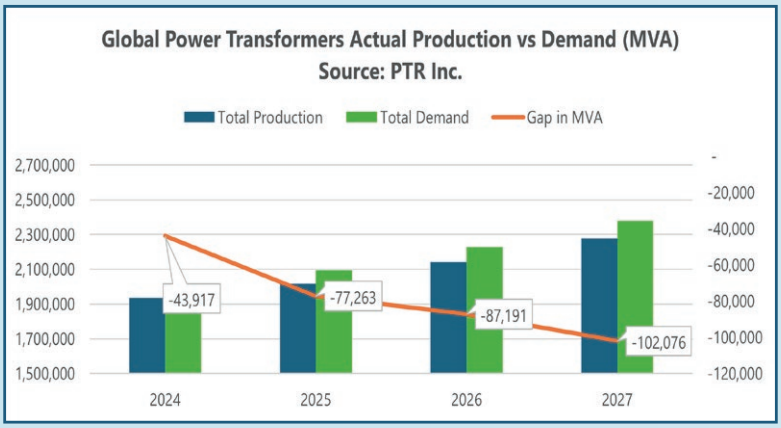

Figure 4.
Global Power Transformers Actual Production vs Demand (MVA)

Although this might change in the next couple of years, as there have been greenfield factory announcements from manufacturers like Elsewedy Electric, EIC and Voltamp, which account for 23% of the global capacity expansion announcements in the next three years. However, even with the newly announced capacity, the region is expected to remain a net importer with an annual gap of around 120,000MVA between the regional production capacity and demand.

South America, despite being the smallest market for power transformers today, is still seeing some movement in the industry. With WEG expanding its production capacity in Brazil and building a new facility in Colombia, according to PTR's research, power transformers production in the region is expected to grow at a CAGR of 2% between 2024-2027. Leading to a cumulative production capacity of 315,800 MVAs against a cumulative demand of 315,850 MVA in the next three years.

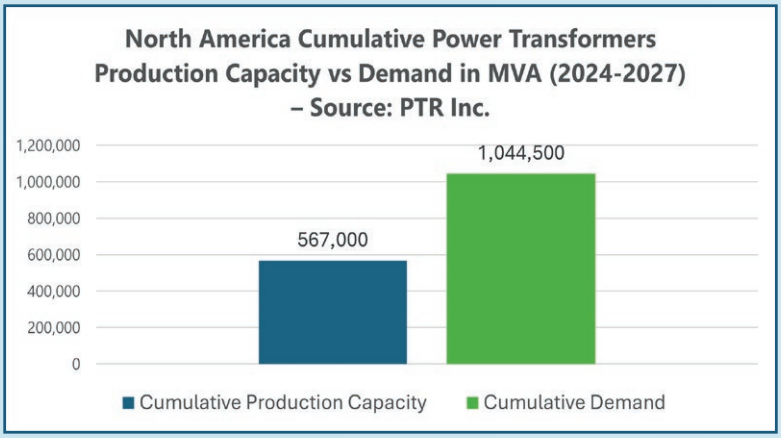

Figure 5.
North America Cumulative Power Transformers Production Capacity vs Demand in MVA (2024-2027)

Europe, on the other hand, has always been a net exporter of power transformers. With several key power transformers manufacturers headquartered in the region, we expect further investments of USD 460 million in production capacity expansions leading to an average annual capacity increase of around 6.4%.
The demand, however, is expected to increase significantly too with double digit annual growth, driven by renewable integration, aging infrastructure, and interconnections within Europe (inter-country, urban-rural). This increasing demand would mean that, despite the region overall having excess production capacity, some medium-small manufacturers will have their order books full supplying to local customers, before aiming to increase their export business.

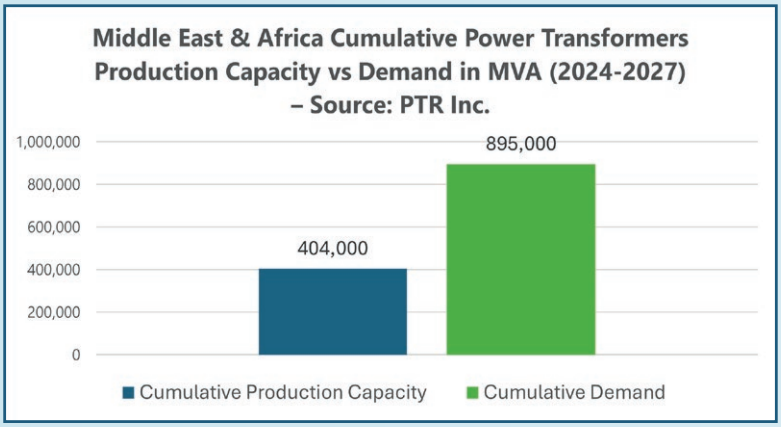

Figure 6.
Middle East & Africa Cumulative Power Transformers Production Capacity vs Demand in MVA (2024-2027)

Asia Pacific is the largest demand and production hub for power transformers globally. The expected cumulative demand in the next three years from 2024-2027 is around 5.5 million MVAs. However, despite this huge demand, the region will remain a net exporter of power transformers with an excess underutilized capacity of more than 1.25 million MVAs per year. Almost all the global excess production capacity lies in this region. Moving forward, the utilization rates are expected to improve with more Asian, especially Chinese, manufacturers investing resources in growing their export business to Europe, the US and the Middle East via direct sales as well as white-labelling partnerships.

Photo: Shutterstock

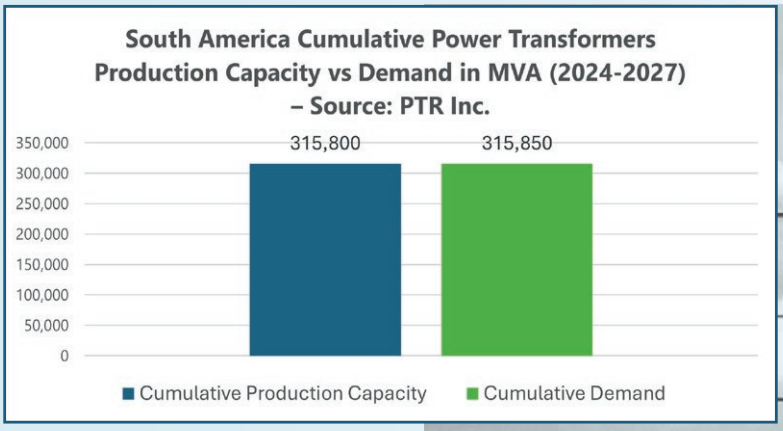

Figure 7.
South America Cumulative Power Transformers Production Capacity vs Demand in MVA (2024-2027)

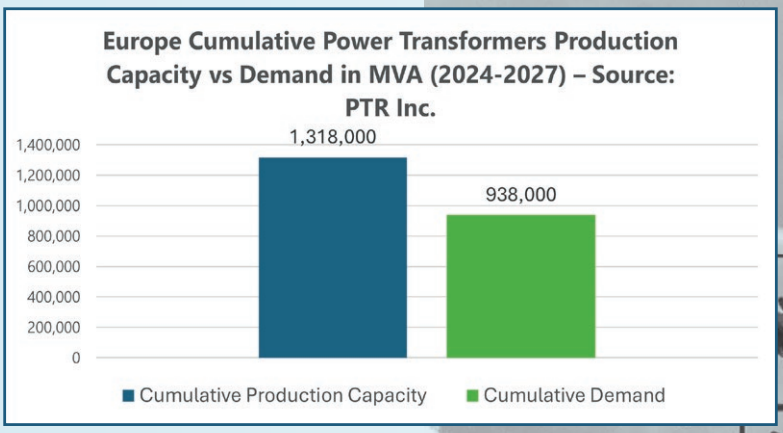

Figure 8.
Europe Cumulative Power Transformers Production Capacity vs Demand in MVA (2024-2027)

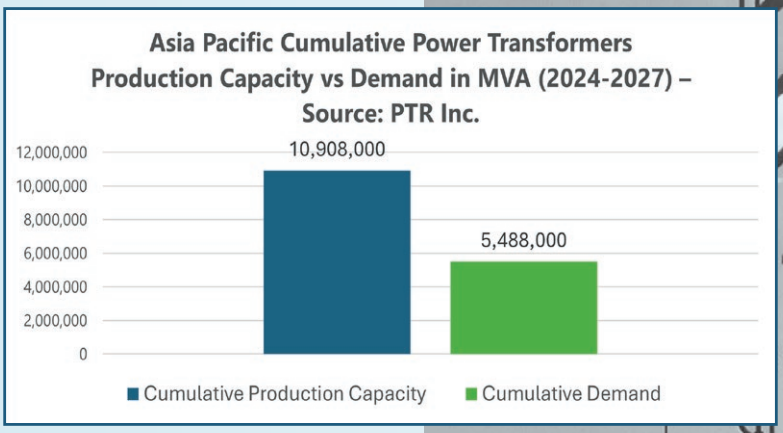

Figure 9.
Asia Pacific Cumulative Power Transformers Production Capacity vs Demand in MVA (2024-2027)

So, what implications does this regional market equilibrium has for the stakeholders in the power transformers space? The answer is in three key takeaways:

- ⊗ First, the demand is sustainable, and the supply-demand gap is here to stay beyond just the short-term. With the current market drivers like renewable integration and aging infrastructure, we can expect the transmission grids needing new power transformers more than ever.

- ⊗ Second, there are two strategic investment hotspots today when looking at the supply-demand balance: North America and the Middle East (primarily GCC). Both regions with their preference towards local manufacturing, offer significant opportunities to capitalize on by investing in local production.

- ⊗ Lastly, any investments in OEM capacity expansions need to be considered in conjunction with other constraints, including skilled workforce shortages and raw material/component supply constraints.

Given all this, the market is still very dynamic, with more strategic investments and partnerships on the horizon. At PTR, we will be tracking these changes in the electrical asset and infrastructure markets and sharing key insights with you in this space via APC Media with you.

Author:
Hassan Zaheer
Partner and Chief Operating Officer
PTR Inc.

Hassan Zaheer is the Partner and Chief Operating Officer at PTR Inc. With more than a decade of experience in the energy transition space, Hassan advises various blue-chip clients in the electrical asset and infrastructure business to sustainably grow their businesses, both through custom consulting work, marketing support services and tailored research by PTR, helping their executive management and boards make data driven decisions. Hassan is also a Member of Executive Editorial Board of APC Media as well as part of the Advisory Board for CWIEME Berlin. Hassan comes from a technical background with a Masters in Power Engineering from the Technical University of Munich (TUM) and a BS in Electrical Engineering from the Lahore University of Management Sciences (LUMS). Additionally, he is also an Alumnus of Center for Digital Technology & Management (CDTM).

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SPECIAL SECTION: Insights from TMAA

TMAA

TRANSFORMER MANUFACTURING ASSOCIATION OF AMERICA

Joe Donovan, Executive Director
TMAA

Tammy Behrens, Director Of Marketing, Communications & Branding, Prolec Energy

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Sandeep Chakravarty, CEO and President
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Alan Ross, Managing Editor
APC Media

Rakesh Rathi, Senior Vice President Operations and Supply Chain, Virginia - Georgia Transformer

> The electrical power industry is a more challenging industry. It's more exciting, and the equipment is bigger, more complex. The people are great. I really enjoy the people I work with and the respect the industry has shown me, both as a professional and as a woman.
>
> **Tammy Behrens**

> We must have a better program to incentivize people to go to technical schools, to learn the skills we need in the factory to be able to build transformers.
>
> **Tammy Behrens**

Alan Ross: I am the Managing Editor of APC Media's publications, Transforming Technology, Power Systems Technology and Women in Power Systems. At the recent IEEE PES T&D Conference and Expo in Anaheim, the 60th anniversary, we had the pleasure of interviewing thought leaders to be able to bring the best of the marketplace to you. Several of those we interviewed are leaders of the Transformer Manufacturers Association of America, or TMAA and we captured their thoughts about what TMAA is all about, the formation of the organization and the mission and vision it has to support transformer manufacturers and suppliers, and by extension, customers, in the power industry.

I first met with Joe Donovan, Executive Director of TMAA and Tammy Behrens, of Prolec GE and current Chairwoman.

How are you Joe and Tammy, good to see both of you again.

Joe Donovan: I am well, thank you Alan.

Tammy Behrens: Good to see you as well Alan.

AR It is a privilege to be here with you, doing this interview so thank you both. First of all, Tammy, tell me a little bit about how you got into the power industry?

TB As the Marketing Director for Prolec, I have been in the power industry for almost 20 years. Back when I started, the company name was Waukesha Electric Systems in Waukesha, Wisconsin.

AR The first transformer plant I ever went to was the Waukesha, Wisconsin plant. It was amazing.

TB Yes, it's an amazing plant, an amazing facility. I started there back in 2005. The company name changed to SPX Transformer Solutions in 2012. And now it is Prolec GE Waukesha. I am the marketing director for all the company's product lines. I enjoy the power industry more than I've enjoyed any of the other industries I've worked in, and I've worked in a number of them. This is by far my longest position, and I see myself retiring at Prolec. The electrical industry is a great industry to be in, and Prolec is a great company.

AR Joe, tell me about why you got involved in it. I know you're with a legal firm that was hired to do this, to do lobbying, et cetera, but you've gotten engaged in it, my friend. You now have transformer oil flowing through your blood as I talk to you.

JD I fell deeply into the chasm of transformers. I'm a power and natural gas lawyer by trade. I've been doing that since 1996, both as a regulator as well as in private practice and in-house at a Fortune 100 energy company. When I went back into private practice, my first client was a transformer manufacturer, Delta Star, and they retained me to help them put together a federal program called FAST, essentially a reserve program for power transformers.

They have a particular product that they were trying to include within that. That's how I got asked to the dance. By luck or grace or stupid luck, I'm not sure, I have been dealing with those issues for 10 years now. With the membership, we had an ad hoc coalition dealing with a lot of import trade issues, particularly with grain-oriented electric steel. That was the birth of the TMAA. We collectively had conversations about how our industry is perpetually reactive, and we're always reacting to pressure points or market changes instead of being proactive. I remember having conversations with that ad hoc group saying, "we really need a Trade Association". It took us five years to get there, but finally, in 2021, we formed the TMAA.

I have been Executive Director now for about 18 months, and we've had great growth. I have great expectations as I am very bullish in this industry. I think if we manage things correctly, it can really help transform both the national economy as well as national security into the future.

AR Remind me to come back to Grain-oriented Steel because that is a big issue that we've got to talk about. But first, I am going back to Tammy to ask why the power industry.

TB I started my career in the farming industry marketing farm implements, and I have worked in the trucking and recreational vehicle industries, at a company that manufactured mirrors for RVs and over-the-road trucks. The electrical power industry is a more challenging industry. It's more exciting, and the equipment is bigger, more complex. The people are great. I really enjoy the people I work with and the respect the industry has shown me, both as a professional and as a woman.

AR I think in Women in Power Systems, we featured you in that. Have we not? No. Well, we will. I will make sure that we do.

Let's go to the issues right now that the industry is dealing with. The first one is lead times. They're astronomical. If all of your members

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are sold out, why have an organization? In truth though, I've never seen the industry come together to try to solve problems that they're creating for utilities and industrials, because being sold out is a good thing. It's also a bad thing if people can't get transformers for this "hockey stick" of growth that we are experiencing.

Data centers changed everything after COVID and industrial manufacturing in America is over 90% capacity in many cases. The average industrial plant, and I'm talking about major power usage industrial plants, is running at 92% today. It doesn't seem like much, but it means you can't stop. Transformers can't fail. If you can't get a new one for three years and you've got one that's 38 years old, it is a huge problem for society and our country. That is an issue that TMAA has got to be looking at, correct?

> We collectively had conversations about how our industry is perpetually reactive, and we're always reacting to pressure points or market changes instead of being proactive... finally, in 2021, we formed the TMAA.
>
> **Joe Donovan**

> We are now making a concerted effort to branch out from that. We have other companies that are in the process of coming on board... we're expanding into a slightly different market.
>
> **Joe Donovan**

JD Absolutely. We spend a lot of time dealing not only with the more macro issues or micro issues of the supply chain, but also what are the policies that are impacting that supply chain? The data you pointed at, 85% capacity, we are churning out all the transformers we can churn out on the current domestic production schedule. The only way to expand upon that is to focus on how we build out more production capacity. Does the market support more production capacity?

I think the answer is yes. We've certainly seen all those pressure points. But what are we doing to help incentivize the expansion of production that includes domestic transformer manufacturing and the underlying components that feed into that transformer? We have spent a lot of time this year dealing with those supply chain issues, coordinating with folks at DOE and at the White House, having conversations with folks at commerce about the impact of trade, trade restrictions, and what is called "Friendshoring", I think they call it nowadays.

What are the countries that we get some of these components from that are not adverse to the interests of the US? And how can we mold all this together into a cohesive policy that addresses the deficit and the lead times and the frustrations in the market?

We hear from our customers. We know that there are pressures that they have. We know that we need to address it. It is not an easy short-term fix either. There are all sorts of underlying reasons why that is.

TB I'll just add to that. Even if the government would give us all millions of dollars to build new plants, we have to be able to staff those facilities. There is a skilled labor shortage. When you're manufacturing transformers, you can't just take somebody off the street, put them into the building. It is not like making a widget, where you give them some instructions and say, okay, make this on this line. You must have skilled labor that can read blueprints and somebody that has technical knowledge to be able to look at something and realize that this goes here, and this goes there.

Sometimes it can take from six months to a year to train some positions, like winders. We have to have programs and help from either the government, private facilities, private agencies or schools where they are bringing these folks up to speed from a technical standpoint. We must have a better program to incentivize people to go to technical schools, to learn the skills we need in the factory to be able to build transformers.

I would say to those who do not want to go to college, there is a great market for people who have technical skills within the US job market.

AR Having worked with a team from the Electric Power Reliability Alliance, lobbying congress and the White House for enactment of the Perkins Act, I can attest to the need to make Technical and Trade Schools a viable career option. These are good paying jobs that are going to last a career lifetime.

TB We do promote a lot in the high schools, in the STEM programs, but the

technical schools really need to graduate people who can do those kinds of jobs.

AR We talked about your role at Prolec. Talk to me about why the chairmanship of TMAA. Obviously, they came calling, and obviously you had to say, "yes I will or will not do that". What does that entail for you?

TB Prolec was a founding member of the TMAA. We are one of those companies that Joe mentioned was instrumental in starting up the group and saying, "Hey, we need something in the industry like this." We are very proud of being an inaugural member of the group.

As for the chairmanship, we had a previous chairperson who was in the role as we started the organization. With it being a rotational role between inaugural members, Prolec was next in line for that, and I was given the honor of being elected as the next chairperson.

JD (Laughing) She hasn't taken a phone call from me since.

TB (Smiling) Now Joe, you know that's not true.

JD In fact, Tammy has been so instrumental and helped me. I was a newbie when she came on board. I had just taken over the Executive Directorship role, and she was very helpful. The primary focus of our first few months was working on rebranding TMAA. She was absolutely critical in getting that from start to finish. On top of all her regular job functions for Prolec, she took a lot of time to help guide a stupid lawyer who doesn't do IT on how to do a website and how to brand and color scheme and all that. So, she has done a phenomenal job.

AR The rebranding of TMAA, what did that entail? New website, color schemes, different things?

TB New logo, new website, new colors, all of that. So, you nailed all those three things. The website is now very comprehensive. It explains a lot about what we've been working on, what we plan to continue to work on. There's a lot of information about our mission and our vision and our goals.

We also give a call out to all of our members on the site. They each have an opportunity to put a little blurb on the site about their companies and what they do. There is a lot of information out there now, and it will give people a good opportunity to know what we do and how they, too, can make an impact and be part of that single voice for the industry.

JD It recognizes a larger trend that we're trying to implement. We were founded primarily by power transformer companies because those were the ones that were dealing the most with the Section 232 compliance issues.

We are now making a concerted effort to branch out from that. We have other companies that are in the process of coming on board that make distribution transformers. We're expanding into a slightly different market. We're also taking a deeper dive into our supply chain by asking who the vendors among our members are that would benefit from the membership and conversely would provide a benefit to the association with their subject matter expertise.

When I have phone calls with the DOE about the volumes of grain-oriented electric steel, how many tonnage are we moving from here to there? I don't have the answers to those things. But with the right membership, I now have a network of folks I can tap into and say, "hey, can you answer this question for me?" So, it is critical that we grow to support the whole industry.

AR Section 232, what is that?

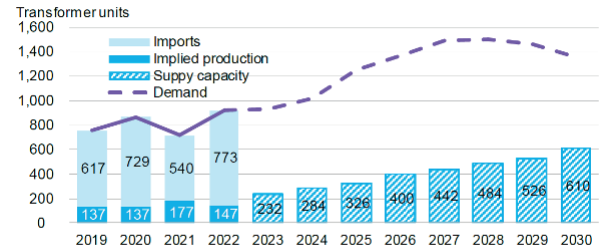
JD That is a tool that the President has to call on the Department of Commerce to do an investigation under Section 232 of the act, and that allows for an analysis as to whether there's national security implications for importation of particular devices or components.

The advocacy in favor of that regarding grain-oriented electric steel has been that there is a national security risk because we don't have enough grain-oriented electric steel production in the US to meet demand, and we are now dependent upon foreign sources. I think that's a very myopic, short-sighted perspective, and we've been very fortunate that, at least with regard to grain-oriented windings and cores, that there has not been a specific 232 application; but all steel imports into the US right now are subject to a 25% tariff. That eats into our margin. We have a very thin margin to begin with, and that eats into it very deeply. The interesting part is that a number of our members cannot use the domestic steel because it does not meet the dimensions that they're able to use in the current modern efficient transformer. So, we are forced into the international markets, and we're forced into the tariff.

> Post-pandemic, customers realized that they're so dependent on the foreign imports that they cannot get projects done on time, so they started nearshoring and started looking at domestic manufacturers. It was a surprise for us. And, all of a sudden, customer preferences changed.
>
> **Sandeep Chakravarty**

> To get the young workforce to work in manufacturing or to attract them to manufacturing is not easy... We have invested in training and development, which I think is very key, which we haven't had for many years. The outreach extends to high schools, polytechnics, community centers and trade schools.
>
> **Sandeep Chakravarty**

Figure 1: Historical supply and demand for US large power transformers, and BNEF's outlook



Source: BloombergNEF, US Department of Energy, Trade Map. Note: Large power transformers refers to units of 100 megavolt amperes or larger. For alternative chart showing transformer capacity, refer to the accompanying Excel spreadsheet.

AR That is one of the values of having something like TMAA. Decisions are made somewhere that affect other people in other ways. And if somebody doesn't advocate it, half the time they don't know. Transformers are the heart of the power system. If we can't increase capacity, if we can't assure a competent, secure supply as a country, we're going to stumble. Any additional information you would like to pass on?

JD We have an annual meeting as part of the TMAA. Generally, it's in DC. Dates have not been firmed up this year. It'll be sometime, probably late third quarter. We will all meet, all the members, and we will invite special guests from the government or from other agencies or associations that we are trying to develop.

AR Let us know and we will get it publicized and get it out there through Transformer Technology. Excellent. Again, thank you so much, Tammy and Joe. This has been great and good luck with the future of TMAA.

Our next interview was with Sandeep Chakravarty at IEEE PES T&D Conference and Expo. He is the CEO and President of Pennsylvania Transformer, a founding member of TMAA.

AR Sandeep, tell me a little bit about how you got involved in the industry?

Sandeep Chakravarty: I am an electrical & electronics engineer by profession with a management degree in international trade. I've been in the power industry for about 32 years across diverse, mature, and emerging markets. Started my career in the transformer industry with CG in 1995 I was a part of a strategic team which made CG, an Indian multinational, into a global player and a major regional player in the Americas.

We grew from a $400 million company to $2.5 billion in 10 years with organic and inorganic strategies. That gave me a lot of exposure to the industry. I started in Southeast Asia, moved to Europe, Latin America, and eventually managed the Americas region for industrial and power products.

AR Did they own Pennsylvania Transformers at the time?

SC CG partnered with Pennsylvania Transformers in the 2000 to increase its market presence in the US and closely interacted with them. I joined PTT in 2019 as COO to turn around the company and create a sustainable business model. During my tenure here, I've built a strong leadership team, used my global experience, technical knowledge, vendor and customer relations to revitalize the business.

Pennsylvania Transformer has a legacy. It has been in business for close to 100 years now with multiple leaderships and multiple ownerships. It is a great company to work for, and results of the various initiatives were very positive. It was a family-owned company with no clear succession plan. I decided to take the company to the market with the approval of the shareholders, led the due diligence efforts, and we sold the company to Quanta Services on October 31st, 2023. This was a milestone in my career and, of course, for the company and for our customers.

For Quanta, it was their first investment into manufacturing. They are one of the largest infrastructure service companies in the US and we were a great synergic fit. They looked at PTT and saw we had great people who made great products. There was a big supply chain disconnect in the industry, and they were not able to complete major projects with the long lead times. Transformers and breakers were critical in their supply chain, and we were a perfect fit. We have tremendous amount of manufacturing space in the facility, especially in Canonsburg. They looked at that and said this is the right company to invest in.

AR So, the best time to get into the transformer business, probably ever in the world, if you didn't in the '60s and '70s, was about 2019, when, all of a sudden, the demand curve has gone through the roof. Talk to me a little bit about that, because we'll talk about the problems that demand curves create. Why did the demand increase so dramatically, so quickly? Everybody's sold out in this industry, globally.

SC Globally, yes. It's not just for the US, of course, but the US has primarily aging infrastructure and supporting legislation fueling growth. First of all, the pandemic exacerbated these issues. The market was, by and large, dependent on the international supply chain which was hampered by delays in logistics issues and delayed getting products on time. The customer perspective changed. Traditionally, when a lot of manufacturing went to China, most of the domestic transformer manufacturers scaled back on production and remained below the radar where competition was domestic. But post-pandemic, customers realized that they're so dependent on the

foreign imports that they cannot get projects done on time, so they started nearshoring and started looking at domestic manufacturers. It was a surprise for us. We had not planned for this growth. And, all of a sudden, customer preferences changed. China changed its policy for data centers. A lot of data centers moved to the US, which need large amounts of power. The renewable strategy with the current government is still very strong, and with this Net Zero initiative, a lot of investments went into renewables. All these sectors grid modernization initiatives, plus EV and battery storage have created this huge demand.

AR You wonder why we were caught so flat-footed. I know that because of COVID the supply chain issues were unique, but we should have seen the demand curve coming at some point because it's not just demand here, it's demand everywhere.

> When we advocate collectively, it strengthens the message that a particular policy or stance benefits the entire industry, rather than just a single manufacturer or a selected few.
>
> **Jared Delello**

> The TMAA plays a vital role in analyzing and communicating policies that can boost supply and identifying decisions that could potentially hinder growth.
>
> **Jared Delello**

SC The scale is different, but yes, the US hasn't invested in infrastructure for so long. Pennsylvania Transformer under its former brand name McGraw Edison supplied transformers to New York City in the early '70s, which are still running. Our equipment, which is designed for 30~40 years of life, are being used for 60, 70 years. It poses a risk to the grid. So that investment, which hadn't happened before, has started happening now.

AR In 1968, I went to Georgia Tech, and I used a slide rule. We overbuilt everything, right? Now we use computers, and we only build to specification. The next generation of transformers, even though they're good, the next generation of transformers will likely not last 60 and 70 years. This is not just short-term. It's going to take decades in order to fulfill the needs that we have. Talk about supply chain issues, how you've helped overcome them, and the labor issues, labor shortages.

SC I'll start with the labor first. We have three generations of workforce in our facilities. As the matured workforce is retiring, this has been a big challenge, not just with us, but across the industry. To get the young workforce to work in manufacturing or to attract them to manufacturing is not easy. There has been disparity in the wage scale. We have unionized labor. We have tried to circumvent that by creating a growth plan for the employees.

We have invested in training and development, which I think is very key, which we haven't had for many years. We have set up a training school besides, of course, the support from Quanta now, which really is big in safety and training. We are trying to scale it down to our level where we can train winders and electricians and assemblers within our facilities. The outreach extends to high schools, polytechnics, community centers and trade schools. We are trying to get people to the facility, give them the skills they need to work in the transformer industry. We need a strong labor force to support our growth plans. That is one of the key strategies that we are following to retain and train the labor force.

AR It's almost a German philosophy where the Germans, the Europeans, trained their own labor force. They did the apprenticeship programs, the training programs. We didn't do that in the United States.

SC We are actually getting into that. Coincidentally, we have engaged Staufen, a German firm to help us with all these initiatives and employee communication. The same common goals flow down to the junior-most employee. Every day, there are communication meetings on Shop Floor Management, we map where resources have to be allocated and track the progress using LEAN principles. They are helping us develop a roadmap for Industry 4.0 in years to come, which includes labor strategy as well.

Unfortunately, the supply chain in the US is not kept up pace with the demand. We have to go global. There is no option. Especially in our industry, copper consumption is the maximum spend. One of our main suppliers decided not to produce CTC conductors in the US anymore,

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which was a very difficult decision for us because they were our main supplier. We had to go international and source CTC copper conductors.

What has happened in the industry because of this disparity in the supply chain is impacting engineering given that our products are made to order. Engineering has had to constantly change schedules to keep up with the varying lead times of critical raw materials and components.

We have not landed into a situation where we are totally at a loss for production. We are vertically integrated more than most of our competitors. That helps us mitigate the issue. We have diversified our vendor base and have used global resources to strengthen our supply chain and build a great team to navigate the challenges.

AR I was talking with Joe Donovan at TMAA and he said to make sure to ask you about a major project that you've got, which you alluded to - expansion. Tell me about the future.

SC We are expanding both of our existing facilities. Our Raeford facility makes small and medium power transformers. We are trying to increase the capacity by 50% there, by improving infrastructure, setting up a new building, and adding new equipment in place.

Our Canonsburg facility produces medium and large power transformers. We intend to double that capacity by 2027. Almost 80% of Large power transformers are imported in this country. We are trying to use this additional capacity to help our internal and external customers to complete their projects on time. We have ordered a lot of different critical equipment to support that.

On top of that, we are starting two new product lines. One is high voltage dead tank circuit breaker, which is, again, in short supply. We had this product line before, which we stopped manufacturing in 2014. Hopefully, by the first half of next year, we will start up that product line in Canonsburg.

Finally, we are starting a greenfield project to manufacture pad mount transformers and substation transformers, which is going to cater to just this high growth markets of renewables, data centers EV charging and BESS.

AR From top to bottom, you have a very integrated product line.

SC We want to be the power products division of Quanta. Our captive consumption is very high for all of these products. Our focus is to strengthen our supply chain within the group while continuing to service existing customers.

AR As a founding member of TMAA, tell me about the value the Association brings to you and to the market.

SC Just as Joe and Tammy have shared, getting our industry together to deal with common issues that each of us as manufacturers face, has been and will continue to be tremendous value. Working with regulators and policy makers, as Joe has alluded to, is critical in making sure we are all working together for the common good which supports nation building.

AR Thank you, Sandeep.

SC Thank you, Alan.

My next interview is with Jared Delello, Pricing and Government Relations Manager at Delta Star, another founding member of TMAA.

AR Jared, welcome, tell me a little about your background and how you got into the industry and about your current role with Delta Star?

Jared Delello: I earned my bachelor's degree in Political Science from Liberty University. A few years after graduating, I joined Delta Star's Contracts team, where I worked on RFQs, quotes, pricing, and bid feedback data. Over the past nine years, I've taken on the responsibility of managing all pricing and overseeing government relations efforts, including handling tariff cases in Canada and the USA and participating in the TMAA.

AR Why did you become part of TMAA, what does it mean to you personally?

JD Delta Star is proud to be one of the founding members of the TMAA. Over the years, we've come to understand the critical importance of the industry speaking with one unified voice when advocating for policies and engaging with political and other institutions. When we advocate collectively, it strengthens the message that a particular policy or stance benefits the entire industry, rather than just a single manufacturer or a selected few.

AR Why is TMAA important to the industry and why now? What has made the organization more critical at this

point in time when transformer demand is going so much?

JD During times of high market demand, the TMAA plays a vital role in analyzing and communicating policies that can boost supply and identifying decisions that could potentially hinder growth. Over the past year, the TMAA has published and sent several policy and position statements to government leaders to address these important issues.

AR What do you believe are the three most important outcomes/activities that TMAA is engaged in for the betterment of our industry?

JD In no particular order: First, engaging with the DOE and the Office of the President to advocate for sound policies. Second, raising awareness within the transformer industry about various programs, such as the Inflation Reduction Act's Tax Credits that can benefit the association's members. Third, sharing crucial information about market shifts, supply chain issues, and other industry changes within the association.

AR Thank you, Jared, I appreciate your perspective.

My next interview is with Rakesh Rathi of Virginia Transformer, another founding member of TMAA. Welcome Rakesh.

AR Tell me a little bit about your background, how you got involved in the industry, not so much with Virginia Transformer, but how did you get involved in the industry?

Why did you pick the power industry?

Rakesh Rathi: When I started my career, I started working for a transformer company, as a mechanical engineer in the design side and that kind of fascinated me from a mechanical engineering perspective. But then, over period of time you start learning things and as an engineer you are always solving problems, analyzing things and then I become more like a transformer engineer which is mechanical, electrical, metallurgy and everything.

From working on the design side, then moving to the manufacturing side, before you know it you have done practically all aspects of the business for the organization.

It is really fascinating because although we say transformers are a mature product and not much is changing, in actuality, different new processes are being used to design and build these critical infrastructure assets.

AR As we speak, transformer demand is at an all-time high. Transformer supply lags demand because you cannot just all of a sudden ramp up your transformer manufacturing, labor, materials, all of those things. Where are we right now in the industry as a whole, as it relates to transformers, what do you think?

RR The demand is much larger than what the industry can supply, especially in North America. Still, we see a lot of imports happening from overseas because of not having enough manufacturing capacity here, so that is the basic situation here. We see a lot of the growth in the power demand with EV's, data centers, storage, renewables, all adding to the demand curve, so a lot of utilities are trying to revamp or rebuild their systems

Since we all have the same issues, TMAA was formed to help us all, as an industry, deal with these issues.

AR Why did Virginia Transformer become part of TMAA?

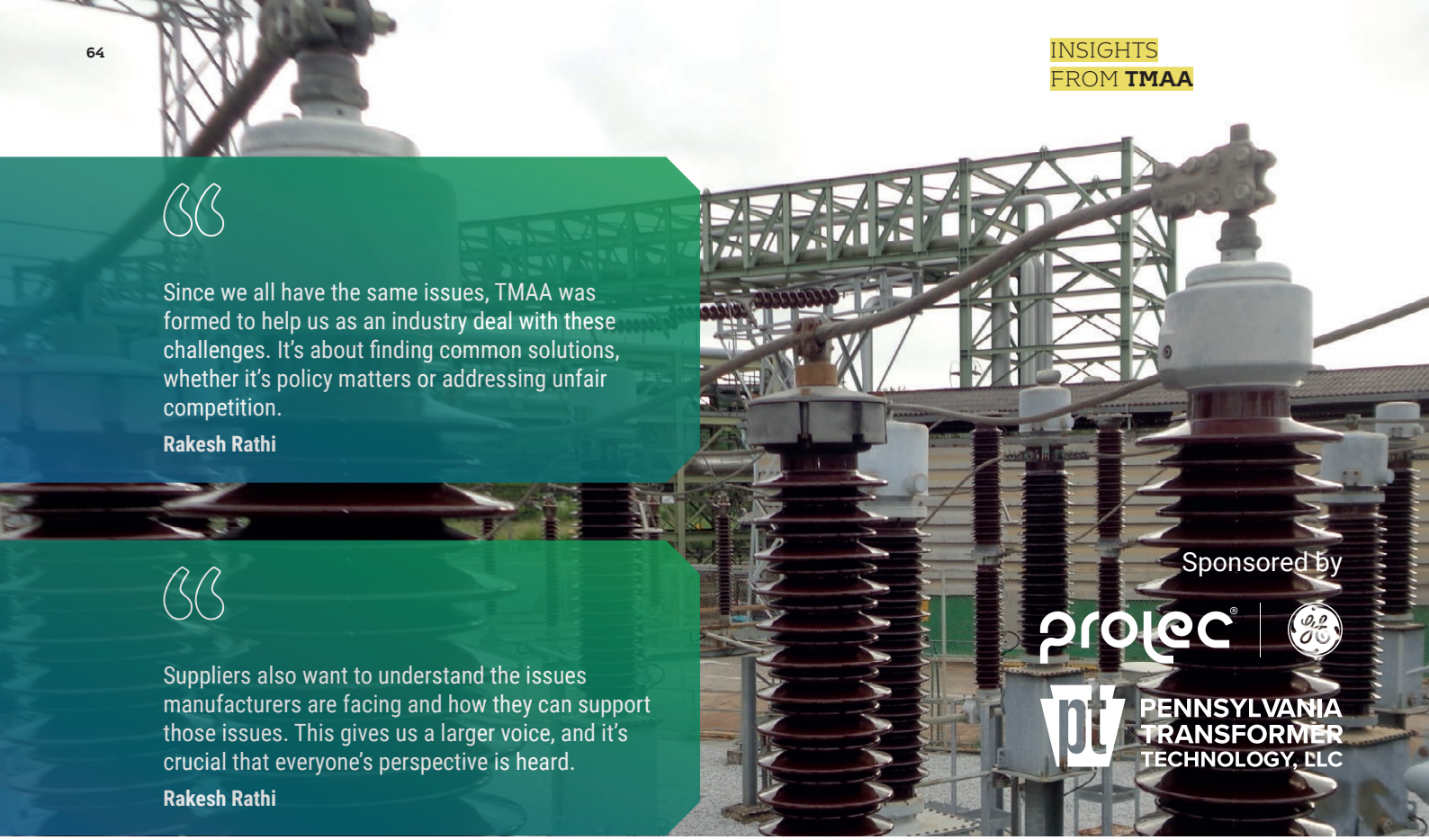
RR As you said, there are the issues, which are common to all of us, so we asked ourselves how we can find a common solution. It could be certain policy matters. It could be fighting against some imports unfairly being brought into the market, which was happening. It was not able to make local industry sustainable, as well as legal, policy and regulatory issues.

Those are some of the factors which give you the idea of forming an association. We can have common issues that we can discuss together, try to solve them out together as one group rather than each one of us trying to do that.

That is how TMAA got started. But even before TMAA we were doing activities as a group, not through a common association, but through partnership and talking to each other because the issues were more or less common.

It originally started with competitors coming together to address common issues, but it has still survived because some of those issues you have to resolve from a policy standpoint or regulatory standpoint, making sure that it's a level playing field for everybody. I think that has happened, but now suppliers have become part of it.

There's a move to make it something bigger than just a regulatory policy group.



> Since we all have the same issues, TMAA was formed to help us as an industry deal with these challenges. It's about finding common solutions, whether it's policy matters or addressing unfair competition.
>
> **Rakesh Rathi**

> Suppliers also want to understand the issues manufacturers are facing and how they can support those issues. This gives us a larger voice, and it's crucial that everyone's perspective is heard.
>
> **Rakesh Rathi**

AR Why is that and what is that?

RR Now suppliers also want to come in to, to understand, what the issues manufacturers are facing and how they can help to support those issues. They also want to have their voices heard within the overall group, which gives us a larger voice as the government is listening to us. We discuss what we need to do to solve those issues so everybody tries to have their voices heard.

We also see people who are not manufacturing-based in the US who want to join our group because ultimately everybody wants to see how they can get some support from us.

As a result, we have accepted companies who are in the North American manufacturing arena, like Canadian manufacturers and suppliers, we have allowed them to become part of TMAA. While we are one of the founding members, the others are either becoming industry members or supporting members. That is what we are trying to do to increase the strength of this group.

AR The last question for you is the issue over transformer steel, grain-oriented steel or amorphous steel. What was that issue and has it been resolved?

RR It has not been resolved yet. As you know, the U.S. government brought in section 232 about four years ago, and sometime in 2020 they applied a duty for any steel or aluminum coming from outside the country. In the US we have only one manufacturer for steel, and they do not have enough capacity to meet the entire demand.

This restriction on imports of the steel it started putting a lot of strain on manufacturing since we can only import a certain form of steel, but not in the other form.

That was the challenge and what is happening now is that the local supplier here in the U.S. realizes that they now have the monopoly. This affects pricing, supply and the ability for the industry to meet this increasing demand cost-effectively. That is the challenge of core steel, or as we call it transformer steel or silicon steel.

AR So, it is still an issue that needs to be addressed?

RR It is an issue. Because of the pressure by the U.S. Government, the same thing is being done in Canada, and we believe Mexico will follow. In North America, we don't have enough of a supply base of the required volume of steel.

This issue is something TMAA is working on when we speak with one voice. That way we can have a much greater impact.

AR Rakesh, thanks for being part of TMAA and thanks for sharing with us.

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Insulation components made from cellulose-based Transformerboard meet the highest requirements specified for use in power and distribution transformers. These components form barriers in the liquid-cellulose (e.g. mineral oil & natural/synthetic ester oils) insulation structure of the transformer. They can be shaped according to the specific electrical field pattern optimizing the amount of insulation material and helping to reduce the size of the apparatus.

Photo: Weidmann

Clamping Rings

Clamping Rings, or Press Rings, apply pressing force to the winding of power transformers and are a critical component in the transformer's mechanical design and strength. They are often designed as a donut-shaped component, compress the winding, and are strong enough to hold the winding tightly in case of a short circuit.

The material used in these components is polyester resin-glued laminated Transformerboard or sometimes laminated pressed wood for smaller units. Compared to wood, Clamping Rings manufactured from laminated board have uniform mechanical characteristics, superior electrical values, and do not release acids during drying.

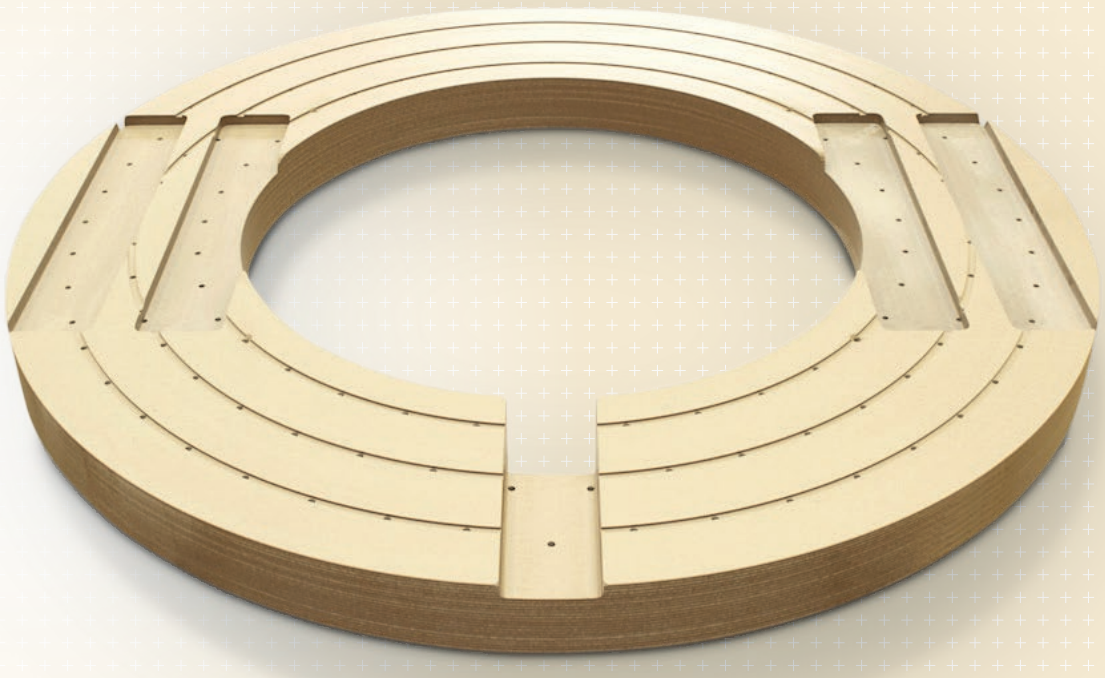
Material Choice

Laminated Transformerboard and wood, used to make Clamping Rings, is a homogenous base material, and, combined with selected high-quality adhesives, ensures the superior mechanical support and clamping structures of transformer windings and cores.

Material selection is based not only on mechanical but also on electrical considerations. Material used for Clamping Rings must meet the following requirements to guarantee long-term performance in the transformer:

- Highest electrical and mechanical strength
- Simple and low-cost machining
- Complete oil impregnation
- Dimensional stability during the process treatment of the transformer
- Favorable aging characteristics

The use of solid insulation materials for oil-filled transformers, such as Clamping Rings, is mostly determined by the electrical stress the materials are subjected to. This information is calculated and controlled by the design engineer.



Pressboard Benefits

Material choice in modern transformers is a key consideration to meet stringent IEC/IEEE requirements and in high-voltage and high-stress applications. Transformerboard components have a range of clear advantages over laminated wood, some of which include:

- **Slower aging and increased reliability** - through reduced insulation degradation, and fewer internal insulation faults which can lead to costly outages or repairs
- **Enhanced operational safety** - where there is a reduced chance of insulation failure, and enables safer operation at higher field stresses
- **Dielectric advantages** - pressboard eradicates the need for plywood veneer butt joints, thus reducing the risk of voids which may not impregnate
- **Increased stress loads** – where Transformerboard components have a higher dielectric puncture and surface (creep) strength and are more robust and reliable

Electrical Characteristics

At higher voltage levels, electrical strength is one of the most important design criteria. Laminated Transformerboard is a high-value material with a very homogenous and stable structure.

A reduction in electrical strength can occur when there are impurities in the material. This increases the probability of transformer test failures. Components manufactured from Weidmann Transformerboard are specifically checked in-line for any metal inclusions to ensure that no conductive particles are present.

Mechanical Characteristics

Reliable data on the mechanical design of insulation components such as Clamping Rings are of great importance to the transformer designer. The mechanical strength requirement for materials is generally measured by two criteria: flexural strength and the modulus of elasticity. The type of adhesive is also an important factor in mechanical strength. Tests to assess mechanical strength should be performed under conditions that conform as closely as possible to real performance in a transformer.

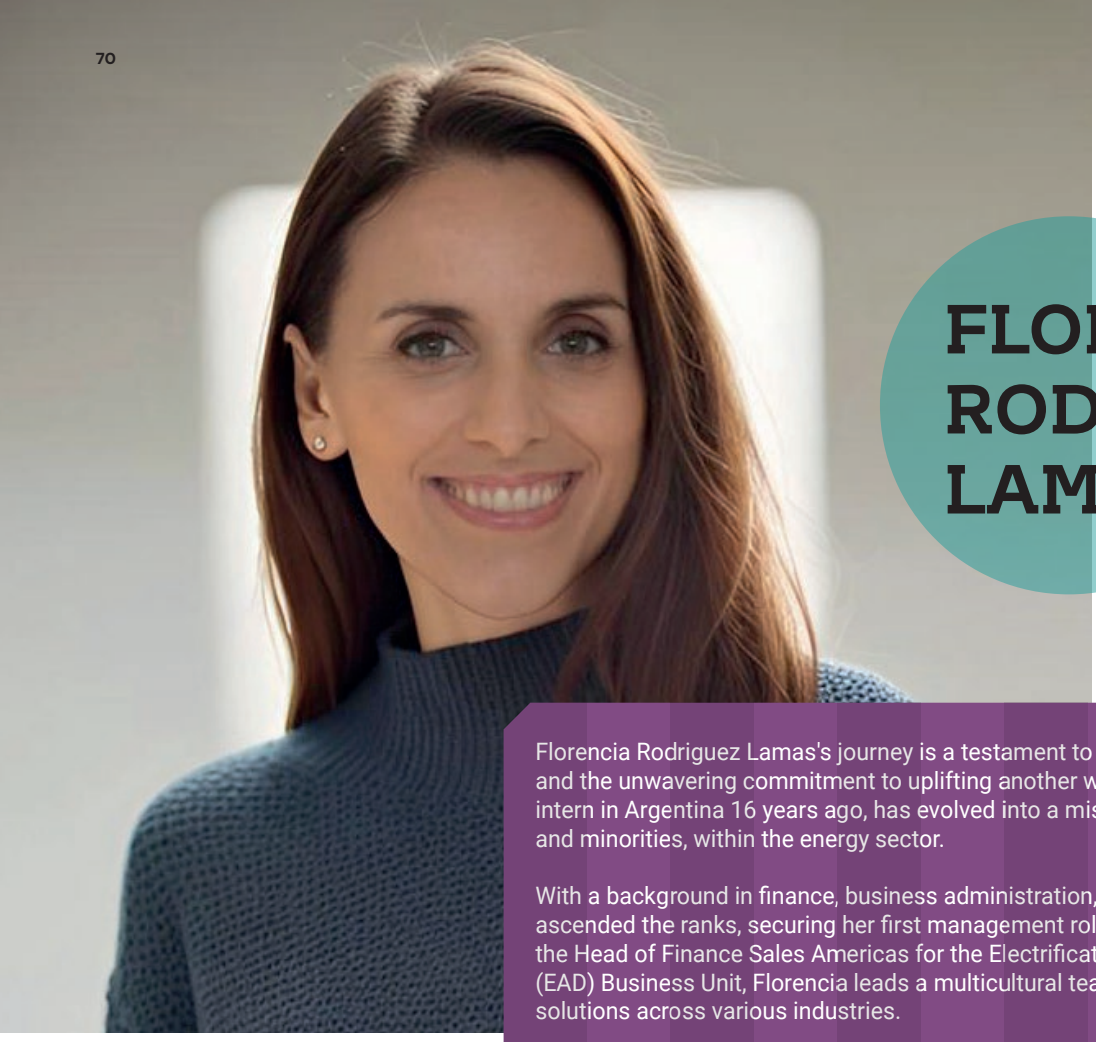
In Conclusion

High-quality laminated Transformerboard components offer transformer designers many electrical and mechanical advantages, including:

- **Enhanced mechanical strength** – the higher density board has superior compression resistance to withstand higher mechanical and thermal stresses
- **Improved dielectric properties** – pressboard's higher dielectric strength make it a safer material option, reducing the risk of partial discharges or electrical breakdown

Weidmann continues to invest in updating its technology to improve product quality and maintain efficiency. State-of-the-art production lines coupled with decades of experience in the machining of laminated board enable Weidmann to meet the increasing demands of the transformer industry.

Photo: Weidmann



FLORENCIA RODRIGUEZ LAMAS

Championing Women in Leadership

Florencia Rodriguez Lamas's journey is a testament to the power of resilience, passion, and the unwavering commitment to uplifting another woman. Her story, which began as an intern in Argentina 16 years ago, has evolved into a mission to highlight and support women and minorities, within the energy sector.

With a background in finance, business administration, and accounting, she quickly ascended the ranks, securing her first management role at the young age of 26. Today, as the Head of Finance Sales Americas for the Electrification, Automation, and Digitalization (EAD) Business Unit, Florencia leads a multicultural team providing decarbonization solutions across various industries.

As she navigated her career, she noticed a glaring disparity: the lack of women in leadership positions. She initiated role model sessions—small roundtable discussions where women could share their experiences, challenges, and strategies for breaking the glass ceiling. What began as a small gathering of 15 participants quickly grew into a global movement, reaching over 1,000 colleagues and becoming a cornerstone of Siemens Energy's commitment to gender diversity.

Recognizing the need for visibility, networking, and mentoring opportunities for women, she organized numerous roundtables and development sessions. These initiatives provided resources and support, empowering women to pursue leadership roles and excel in their careers. This led her to take on various roles within Siemens Energy's Employee Resource Groups and the Inclusion & Diversity Council, where she championed cultural awareness and celebrated the rich diversity of the workforce.

One of Florencia's most impactful contributions is the "Girls with Energy" program, which she helped launch in the US after its success in Latin America. This initiative aims to inspire young girls to pursue STEM careers by engaging them in hands-on projects related to the energy sector. The program has been a resounding success, with over 80 girls from 12 states participating and showcasing their creativity and innovation. The initiative is helping to build a pipeline of future female leaders in an industry historically dominated by men.

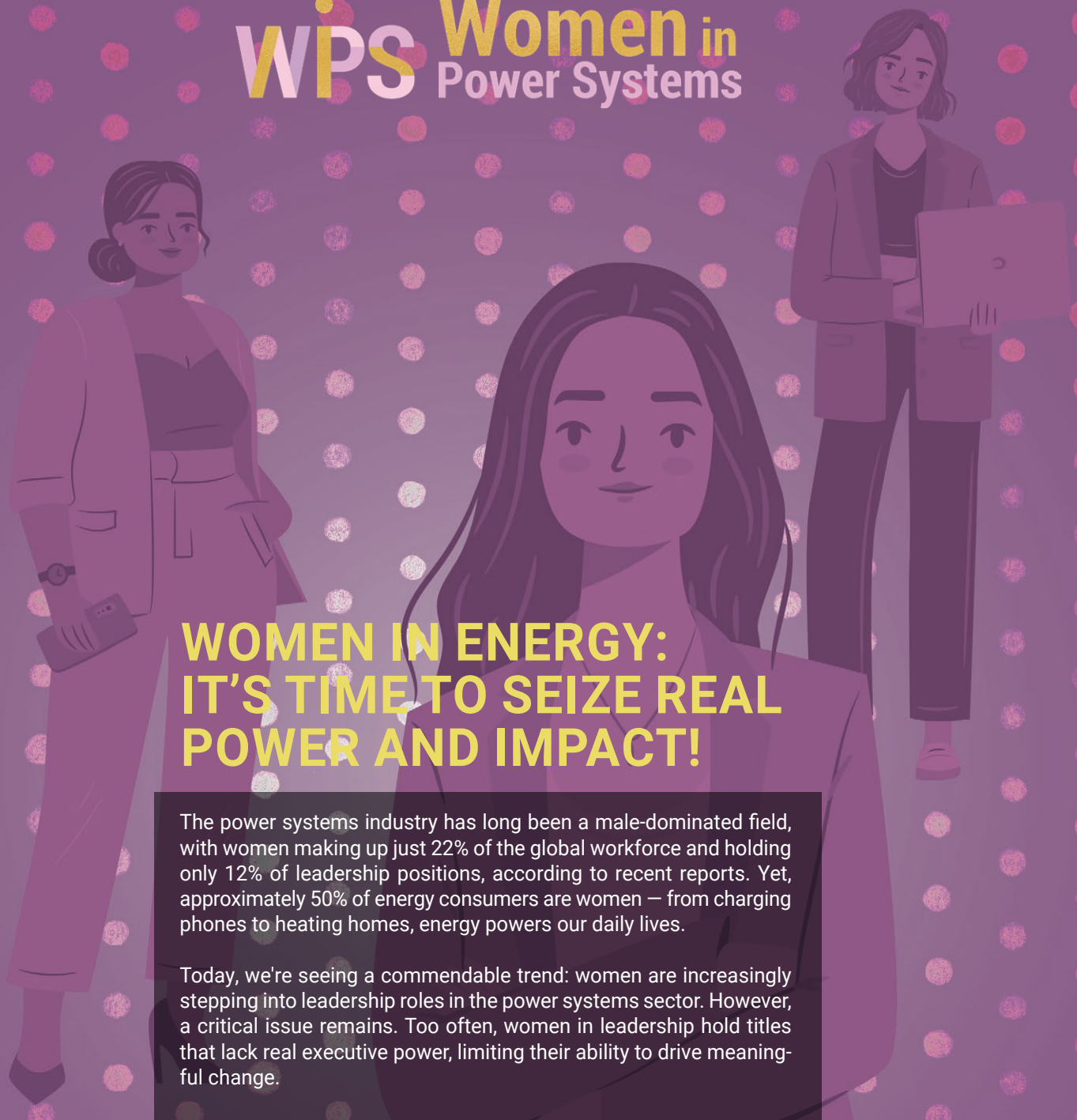
Recently she played a pivotal role in establishing the Orlando Chapter of the Women in Energy Network, a platform that offers networking, mentoring, and leadership development opportunities for women in the energy sector. This chapter is set to become a vital resource for women in Florida, fostering connections and providing a supportive community.

Florencia's achievements have recently led to her appointment as the Global Gender Champion on the Global Inclusion & Diversity Council at Siemens Energy. This new role is a significant addition to her responsibilities and a recognition to her dedication to driving gender parity and inclusivity on a global scale.

Reflecting on her journey, Florencia Rodriguez Lamas acknowledges the profound impact it has had on her personal and professional growth. Her passion for people's development, coaching, and mentoring has not only shaped her career but also inspired countless women to pursue their ambitions with confidence. Florencia has created a platform that highlights women's achievements and provides the support, and resources needed to thrive in leadership roles.

SIEMENS energy

WPS Women in Power Systems



WOMEN IN ENERGY: IT'S TIME TO SEIZE REAL POWER AND IMPACT!

The power systems industry has long been a male-dominated field, with women making up just 22% of the global workforce and holding only 12% of leadership positions, according to recent reports. Yet, approximately 50% of energy consumers are women — from charging phones to heating homes, energy powers our daily lives.

Today, we're seeing a commendable trend: women are increasingly stepping into leadership roles in the power systems sector. However, a critical issue remains. Too often, women in leadership hold titles that lack real executive power, limiting their ability to drive meaningful change.

How do we address this imbalance?
We've posed this question to engineers, CEOs, and team leaders from top companies in the industry, sparking vital conversations. The journey towards equal representation is ongoing, but we aim to be part of the solution. By fostering discussion, building a strong community of women professionals, and amplifying their voices, we can drive progress and ensure that women are not just present but leading with real impact.

Support and elevate the voices through Women in Power Systems.

Contact: Managing Editor: Tamara Marček tamara.marcek@apc.media

WOMEN IN POWER SYSTEMS
BE THE VOICE OF CHANGE

Randy Williams

Business Development Manager
at North American Substation Services (NASS)

Interview with **Randy Williams**

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Alan Ross: Randy Williams, thank you so much for joining me at APC Media. First of all, what are you doing right now? I know you are currently with Voltyx, who recently got acquired along with NASS and EPC as part of the Asplundh family of companies. Tell me a little bit about it.

Randy Williams: After 44 years in this industry, I'm very excited to be a part of the Asplundh portfolio of services and products. I always thought of Asplundh as the tree company.

AR The tree services company?

RW Yes, I always thought of them as that too, but now that I am part of it, there is so much more. They're not just tree trimmers. We do storm management, emergency management, and vegetation management. But we also have another group, the infrastructure group that is engineering construction of underground overground substations, that type of thing. Adding Voltyx, North American Substation Services (NASS) and EPC, and our protection control group; we all fit right into the family of companies. I am really excited to be part the Asplundh group. It is exciting to be a part of something that has been around for around 100 years.

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AR Since you shared this with me, I did a bit of research. I like to look at companies based on finding the core of a company. What is their culture? You just said it: Asplundh is a family company, close to a century old. They are lucky to have you and you are lucky to be part of that portfolio of companies serving the power industry.

When we first met, we were guest speakers at an event. You came up after me, and when you got off the stage, my thought was, "oh my gosh, I never have to worry about finding an expert on bushings ever again". You were that good. Little did I know you had become an expert at other things, too.

Randy, you have been my "go to guy" when I needed someone to help our community understand the "then and now" of bushings, or when I just needed a refreshing inspirational guest interview, so here we are again. Thank you. Talk a little bit about the history of bushings and your role at Westinghouse then ABB.

RW Well, I think when we start talking about bushings, I almost have to want to take off my jacket and loosen up my tie a little bit and get a little bit real. I've been in the industry now since about 1980, and in 1980 I was Westinghouse. It was not ABB at the time.

At that time there were two major players making transformers in the United States. You had GE and Westinghouse, who competed against each other. Westinghouse actually manufactured bushings for themselves, for their factories. GE also made bushings for themselves at their factories, but GE also made bushings and sold them to other factories outside of their own GE factories.

In 1980, Westinghouse wanted to consolidate, because we were making bushings in three different factories. GE had a bushing that was called the Type U. That was about 75% of the industry at the time. That was probably about 22,000 or 23,000 bushings a year from 25 kv through 800 kv.

Westinghouse was making three different types of bushings in three different factories. To consolidate bushings manufacturing they located an existing factory in Alamo, TN. In Alamo at the time, they were making transformer rectifier units, air core reactors, and oil instrument transformers. Actually, I was an oil instrument transformer winder on the floor.

That is how I started. Westinghouse built a Type O bushing before 1980. And when they brought it to Alamo, they redesigned it and called it Type O+. In about 1985 GE said, “we're going to get out of the transformer market and when we get out of a transformer market, we're not going to need to be in the bushing market anymore.” They had 75% of the market share with bushings at the time.

We had a young man who was an Engineering Manager in Alamo at the time by the name of Harold Moore. Now most everybody knows Mr. Harold Moore across the industry. Harold said, “why should we try to keep doing what we're doing? Let's go get those drawings”. Because they bought the GE technology and all of the drawings - 20 or 30 million drawings from 20 mva and up - and all the bushing drawings, and if they already have 75% market share, “let's take their GE shell”. At the time they had a condenser problem. It was called the herringbone condenser problem.

They started having bushings that were failing in the field at the time. Westinghouse had bought a technology in 1980 from a company called Micafil AG in Zurich. Micafil had this design that was a printed ink design also, but it was individual sheets, capacitors built in. It was not a herringbone design. Micafil had been building this bushing for 20 years with basically no failures in the field. We took the GE shell with 75% market share and Harold says, “let's take the Micafil design”, and that’s Westinghouse now. “Let's put that condenser that hasn't failed in 20 years inside that GE shell”.

Photo: NASS

They called it Type O+C. The C meant composite.

Most people today, when they hear composite, they think of different materials, silicon rubbers and resins and things like that. But if you look up the word composite in the dictionary, it just means a group of parts put together. That is what they did. They took parts from GE and from Westinghouse and the Micafil design condenser, and they married them all together to form the Type O+C. Since 1986, we had probably 65% to 70% of the market share within the US.

AR And they are still out there today.

RW Yes, there are tons of them. That bushing is an oil impregnated condenser bushing with a porcelain insulator which they still make today. Everybody wondered why Micafil would license this technology of the condenser to Westinghouse and basically give it away and share this technology for Westinghouse to build. Well, what we didn't really know is that Micafil had dropped oil impregnated paper in 1980, moving exclusively to resin impregnated paper in 1980.

There was a technology change around the rest of the world, and we thought we were getting the best technology, but they were already coming in behind us with a new technology. Since everybody thinks RIP, a resin impregnated paper condenser, is a new technology in the US, we are just not familiar with it. And US utilities don't like change unless they have a history with the technology.

Micafil has been building RIP bushings since 1980, so it has been around a long time. I wrote the marketing plan for ABB in 2000 to change to dry type bushings because we saw the need for it environmentally. People were trying to get rid of oil. If it's a high seismic region, a lot of times, large bushings that are porcelain, that are very heavy, can't withstand a high seismic.

Then also, you have security reasons in the United States where people want to take “pot shots” at bushings or transformers and things like that. For years RIP technology used porcelain insulator on the upper end and then we moved to a silicon rubber. They had RTV at first, which is not a high grade of rubber, and then changed to LSR, which they still make today, which is a liquid silicon rubber that is molded. You also have HTV, which is high temperature vulcanized rubber. Westinghouse had to decide at some point, too, with oil impregnated paper bushings with insulators, because they had their own insulator factory. Porcelain was made in two places in the United States, and one of them was a competitor of Westinghouse at the time, who was making their own insulators. Suddenly, insulator companies folded in the United States, and now they are being made in China or elsewhere. Lead times of bushings with standardization within the IEEE standards suddenly expands and we know how important IEEE standards are to the industry. Even if you standardize, people want bushings in two weeks, four weeks, six weeks. If it's a replacement, they want it today. But when lead times grew to 24 weeks, that was and is still difficult to manage. What bushings manufacturers have to do is stock boatloads of porcelain on the bet that they're going to get orders.

So that changed the philosophy, too, of moving towards silicon rubber insulators that we could make ourselves and not depend on porcelain manufacturers. But it is hard to make that switch, to meet the demand right now. We know what the demand for transformer manufacturers these days is three, four, five-year lead times. Well, there's a big demand on bushings for all of those transformers coming in, and my approximate guess of new transformers coming into the US is probably between 3000 and 3600 a year new, whether it be for renewables or utilities or industrial and commercial.

We know what the demand for transformer manufacturers these days is three, four, five-year lead times. Well, there's a big demand on bushings for all of those transformers coming in, and my approximate guess of new transformers coming into the US is probably between 3000 and 3600 a year new, whether it be for renewables or utilities or industrial and commercial.

But there are probably 200,000 old transformers in service across the United States, right? And they all typically have seven bushings on them.

So, bushings become more important as these transformers age and are being operated well beyond their design life.

I was at the transformer switchyard users' group, which is nuclear generation, and they are seeing more failures today as well. Not just older bushings, but also newer bushings. Is it because the utility industry is losing expertise to know how to maintain or identify problems in the field? At first, when RIP technology came on board, they were very defensive. No monitoring on bushings. Now we are seeing more people with monitoring devices because they don't test as often but when you monitor, you are tapping into the heart of the bushing.

I just bought a brand-new Corolla the other day and If I put something on that Corolla, on the engine or the electronic system, that was different from what came from the factory, they would tell me my warranty was void.

AR Correct.

RW And the same thing happens with bushing manufacturing. I do see the advantage of monitoring these days because there are other influences that affect failures on bushings, other than just the bushing failing. It could be overheating or lightning or a squirrel or frog or a snake or a bird or something like that. I do see the need for monitoring in the industry, and it's shifting toward that direction as we look at history.

The next change has been from RIP to RIS. RIS is a resin impregnated synthetic. Because we know how utilities store bushings as spares. RIP bushings, in lower end, the paper can take on moisture if it's not properly stored. We know they store them everywhere, inside, outside, if they can even find them when they need them. But the RIS, in the lower end, doesn't take on the moisture. So, it's better for people with, with spare bushings in the field.

The fact that the demand is there, and it is hard to turn one faucet off from OIP that we are still selling because of the demand and turn to RIP

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or RIS to fill that growing demand. Right now, I think it is a supply and demand thing that is holding back the transition from OIP into RIP or RIS, or in the silicon insulators. The demand is too big right now.

AR Is it possible to retrofit an OIP wit an RIP or RIS?

RW Here is the key Alan, if you bought your transformer per the IEEE standards and stated IEEE bushings, that standard has dimensional requirements besides electrical requirements and testing requirements and things like that. If they bought to IEEE standards, the RIS bushings and the RIP bushings, then they are one for one fit. And fit is one of the most important things when you are going to replace a bushing because if the fit is not proper, if it is too big to fit the hole, or if it is too long inside, then you lose clearances inside the transformer and the transformer guys are going to throw their hands up and say “nope”. You. When you lose the clearances, especially with an aging transformer, it could fail on you or go catastrophic. But, if you bought to IEEE standards, it will be fine. I know I am pushing IEEE here again, but is important to be involved, be a part of IEEE, vote, attend.

AR Last question for you. What is next for you? You still seem to be enjoying it. You've been in the industry a long time.

RW You know, I am kind of like you. Everybody thought I was going to retire six years ago, right?

AR I thought you were retired.

RW No, I still travel, close to 250 days out of the year. It is all about relationships. It is about knowing the pulse of the industry. And if you don't have your finger on it, how it's changing and moving, not just technology, but the people and what they starve for, or what they need, or the new requirements that are there; if you're not on top of it, then you're not on your game. I like to be on my game or ahead of the game, and I still just enjoy people. One of the best things I enjoy is an interview with you. It's exciting to be here. I'm really excited about Asplundh, how I can grow and learn.

AR That is one of the things I love about you Randy, you have always been very open to sharing, taking your knowledge and sharing it. Young engineers would be wise to buy your book if you had one. Write a book, by the way. History of bushings and we will publish it. They'd be wise to buy your book, and either that or buy you lunch.

RW Mister Harold Moore told me I was the best salesman that he had ever met who never sold anything, and that I only tried to educate people to make the right decision. And it's how you position yourself to educate people to make the right decision. Is the right decision OIP, RIP or RIS? Which is the right application for them? Education, to me, is the best thing.

AR Thanks, Randy. This has been wonderful, as usual. Let's make sure that the next time we speak, at an event they let both of us get up on the platform and we'll tag team. That would be brilliant.

RW That would be fantastic. You take care, Alan. Thank you so much.

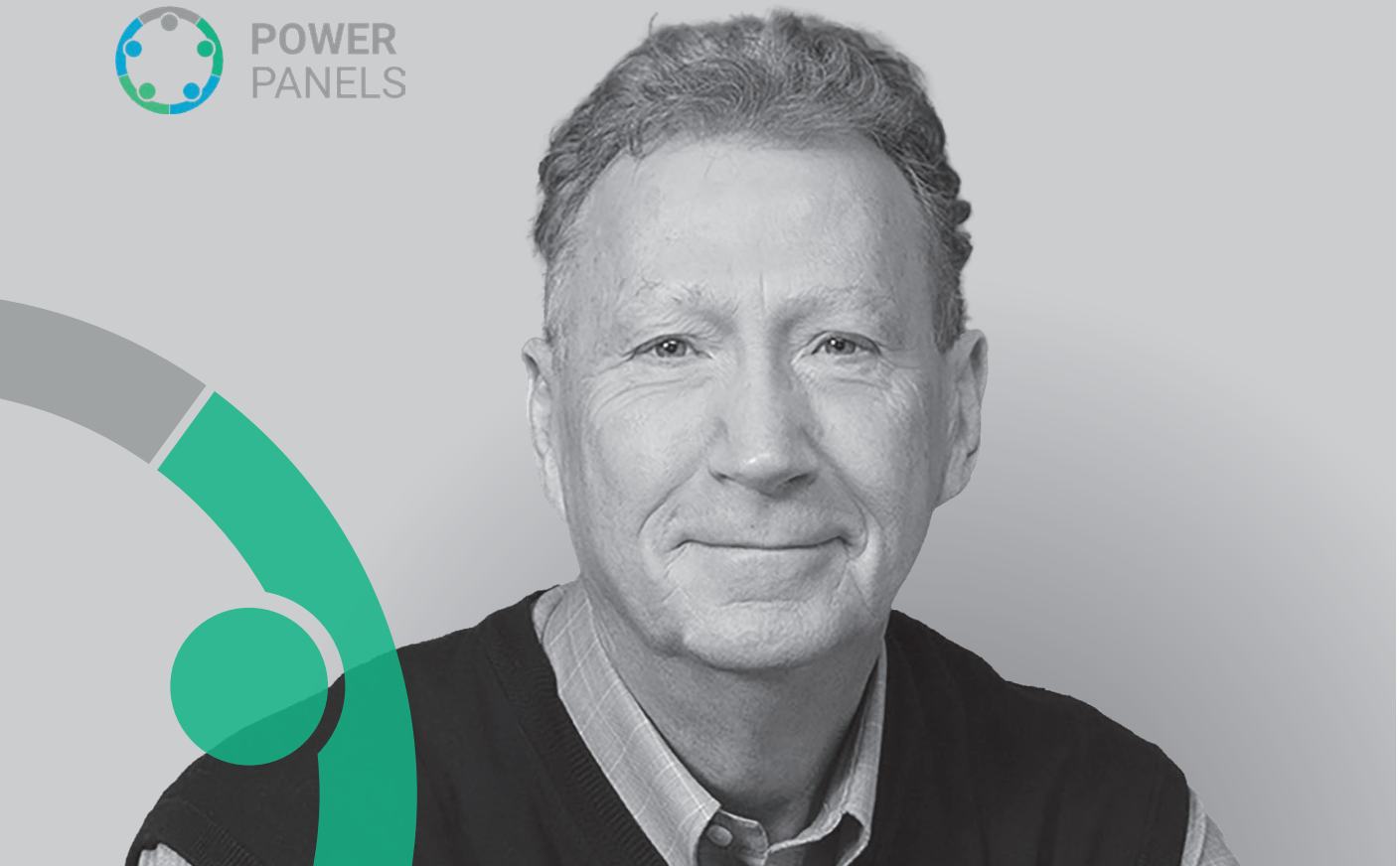
POWER PANEL

John Ulcar
Founder and Director, Crosslink Technology

Jeff Door
VP of R&D, The H-J Family of Companies

DISCUSSIONS

Marco Tozzi
Senior Technical Advisor, Camlin Energy



Alan M Ross
Managing Editor, APC Media

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>
> **John Ulcar**

Alan Ross: Hi, I'm Alan Ross. I am the managing editor of APC Media, and we are presenting a power panel. My guests today are from a diverse group of companies. We have got John Ulcar, who's the Director and Co-founder of Crosslink Technology. John will be sharing a little bit about himself. We have Jeff Door with us, who's the VP of R&D for the H-J Family of Companies, and Marco Tozzi, who is an old friend and has done this with us several times. He's a Senior Technical Advisor for Camlin Energy.

Gentlemen, if you wouldn't mind, you're going to do a little bit about a quick intro about you and your company. John, go ahead and start for us.

John Ulcar: Thanks Alan, I am the founder and owner of Crosslink Technology. We are a company that does formulating for the electrical-electronics industry. We supply products for the casting of dry type transformers, PTs, CTs, and various coils and windings, as well as cast our own electrical components, mainly transformer bushings.

AR Jeff, tell us a little bit about your background in the company.

Jeff Door: I am Jeff Door, VP of R&D, the H-J Family of Companies. I have degrees in mechanical engineering and engineering management. I also participate in the IEEE Transformers, Switchgear, and Insulated Conductors Committees.. I have been with the company for 22 years. I began as an engineering intern and had various roles in design engineering, design of components, machinery, and testing throughout my career.

AR Marco, a little bit about yourself.

Marco Tozzi: Thank you, Alan. My background is electrical engineering, and my PhD was on partial discharges at the University of Bologna. I've been working for Camlin Energy for 12 years now, and recently we created a new department, Asset Performances, which I am the director of, focused on providing expert services on HV assets to our customers.

AR Before we get into bushings or monitoring or a lot of the changes that are taking place within that part of the industry, let's talk about the challenges and the changes that are going on in the power industry in general. What do you see? Because right now we have a demand for transformers that is far exceeding our supply. Everybody's trying to meet that demand. John, I know you are a student of the industry as well, so talk about your perspective of where we are.

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JU The Department of Energy is predicting a 260 % growth in the next couple of years, just in the demand for power. But on top of that, with more building of high voltage transmission wires, there's going to be a requirement for more transformers, obviously, and more bushings. It's also estimated right now that about 35 % of the current transformers are near the end of their useful life, and they're going to have to be replaced.

But there is another thing that I'm not sure is totally obvious to a number of people, and that is because of environmental factors and weather events, such as more hurricanes, stronger storms, a number of utilities are going away from pole top transformers to padmount transformers, which, again, is just another stressor in terms of demand. Another thing I think could be a bottleneck is that the supply of steel for transformers is a real issue.

AR The Transformer Manufacturers of America Association, TMAA, is an alliance partner of ours, and they are working mightily on that issue of steel for transformers. Jeff, your thoughts on the industry?

JD As John said, we have unprecedented demand right now. We are as busy as ever. Challenges in supply chain have not impacted us too much but is something that we are closely watching. We maintain very good levels, having months of a lot of the inventory. We do a lot of porcelain assemblies, and anytime you're importing components like that, you must make sure you have a good, steady supply.

For me, resilience is all about recovery. And as Ken mentioned, there are many aspects to that. To build a resilient grid, you need a significant amount of infrastructure and data and information, and to be able to do that, you need to have the ability to understand what it is that you're looking for and what these events are that are occurring. For instance, if it's an event like a tree that goes onto a power line, maybe a recloser trips or power comes back on automatically, that's an automatic situation that occurs. It's resilient. It's recovered on its own. So that's how I see it.

AR Marco, your thoughts on the industry in general?

MT Jeff and John are on the supply of components and bushings but I see the other side of the coin of what happens in the field, because we help to assess the condition of the bushings, and the condition of the transformers.

And as you said Jeff, it's challenging because there is this crazy balance between being inexpensive, reliable and flexible. We see transformers with bushings in very bad conditions and you can't do anything because you don't have a spare bushing. Sometimes, to replace the bushing, you have to replace the GIS connection and to do that you must change the layout of the substation, so it is often better to change the entire transformer if old enough. Until you do that, you just pray that the bushing doesn't explode. We have phase shifters here between Italy, France, and the rest of Europe. No new transformer will easily fit the footprint where the transformer is. So there is a balance where you must push your asset beyond the end of its normal useful life and at the same time guarantee reliability high standards So, you must maintain what you have and plan what you don't have because you need five years to get a new transformer, like in the US. I see this also in Europe, the transformer is ready to go, but the bushings or OLTC are not available because they come from another supply chain. A small component will get everything stuck. It is quite challenging.

AR Thank you all. Jeff, one of the things we're seeing throughout the industry is a lot of technical advances. People are using this time to make technical advances and/or innovation within their scope. What is happening within the bushing supply chain that relates to innovation and technical advances?

JD There are a few things. One is with some of the connector bushings. By IEEE standards they top out at 35KV, whereas in Europe they have higher voltages. We are having a discussion in the IEEE Insulated Conductors Committee on how to push that IEEE Standard higher. The market demands some of these components quicker than the standards can respond to them, so we are keeping up on that.

Also with the increased transformer capacities, particularly in renewables, they are running transformers up to ratings and sometimes even over them. Things are running hotter and the components need to meet those demands. We see a lot of on and off, particularly with solar, go from 0% to 100 % when the sun comes up. Not only do the bushings and other component materials need to handle this, but the bulk installation also needs to be able to handle it. Gaskets are also something you must consider, and not just from the temperatures we are seeing, but from compatibility with all the different fluids that are being used now.

AR John, Crosslink is at the forefront of a lot of technology advances as a company. Share some of that.

JU We are looking at it from three points of view at this point. One is, as everybody knows, porcelain bushings, just by their nature, are very good at self-cleaning. They have great longevity in various environments. We are working on developing new epoxy formulations that have better improvement in terms of surface energy and

> “Even if the insulation itself can handle the overload conditions, even common industry standards allow for thermal short time currents. It can be 25 times operating current for a short duration, but it can also allow the bushing to reach temperatures where some damage, some loss of life of that gasket, can occur.
>
> **Jeff Door**

water resistance and to give longer life in terms of the not contaminating the surfaces.

The other thing that we're working on, which I think is exciting, and I think Marco might appreciate, is that we are coming up with insulating materials that would be self-healing during a partial discharge event. So that would obviously prevent the deterioration of the insulating material.

Again, if we can eliminate partial discharge at the initial event, it will prevent deterioration. And lastly, which is something everyone is thinking about nowadays is developing more ecofriendly epoxies that are not based on oil but on plant-based ingredients. That's a little bit more of a challenge that with time, I am sure will develop as well.

AR Many industrial and commercial utility customers, and the utilities themselves are making sustainability one of their corporate goals. That puts a requirement on the suppliers of transformers and other assets, which puts that requirement on you because everything you do for sustainability gives them credit, but before we go there, Marco, I want to go back technology and change. You can start with self-healing of partial discharge that John mentioned.

MT There are three technologies available for bushings. One is oil impregnated paper, OIP. The other one is the resin impregnated paper, RIP, and the new one is the synthetic resin bushings, RIS. Give or take, 80% of bushings today in the field are OIP. RIP is growing and RIS, while not yet in the mainstream, they are coming. Every one of these different technologies is trying to solve some problem. For example, resin changes the game in terms of being eco-friendly, reduce the risk of explosions, for example. Synthetic ones, for example, replace the paper in order to have less aging due to moisture entering. For RIP bushings, one of the problems is partial discharge because that material will not withstand a partial discharge. And we have seen this by monitoring these bushings that sometimes you see the PD due to a cavity, and the cavity then evolves in a short circuit between the layers.

We think the future is looking at synthetic materials, synthetic fibers, like in transformers using synthetic esters. Now, we are still dealing, of course, with the oil impregnated paper.

AR John talk a little bit more about collaborating with customers, where your engineers are working with engineers, not just at the OEMs, but also with the utility company, correct?

JU That's correct. They are trying to innovate as they are involved in dealing with tighter spaces. Dimensions are becoming much more important. Even the way we're connecting things, the components together are all becoming much more unique. Years ago, we were given a drawing by our

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customer who said, “Can you make this, yes or no?” There was no room for development. “Can you make it and what's your price?” Whereas now, customers are talking to us about developing products that can be maybe able to handle a higher electrical stress, a higher mechanical stress under certain conditions, and if we can make parts designed in such a way to meet those requirements and to fit within the spaces that they're limited by at this point.

AR Jeff, talk about collaboration with your customers, and collaborating with their customers to bring about a new product, a new technology, or solve a problem.

JD We have seen all the way from, as you said, a drawing, making it exactly like that, and we can do that. But those aren't the fun ones. We like to work with the customers where sometimes they just bring us an idea. They bring us constraints. We need constraints to be able to have somewhere to start. And we work alongside them, passing ideas back and forth. We have several experienced people in our engineering department where we do 3D modeling, we do simulations, electrical, mechanical. We do flow simulations for our epoxy moulding and casting as well, and then make tooling in-house, source all the components. And we have a high voltage test laboratory. We're able to do the testing for the customer. We've even had customers come in, witness their testing, and we're working alongside each other to make changes and to develop the product together.

AR That is the future. Marco, I know at Camlin, you are working on many projects, but the same thing happens. Talk a little bit about your experience with collaboration.

MT Yes, it has changed a lot in the last 10 years, I would say. It is now more about, “Can you really support your customer to find what the problem is, to find the solution?” Completely different. We now give a multi-year service to analyze the data, to understand the data, because otherwise, you just have monitors that don't give any information. With some customers, it is possible to proactively operate in a way that you can find the problem.

For example, we published a paper years ago where we found a problem on one bushing. And thanks to that problem, finding what the problem was, opening the bushing, they could save a number of transformers and replace the full batch of bushings with a potential problem. From one bushing, you save maybe 20 transformers. And this was thanks to the asset manager, the subject matter expert of the company who wanted to find the problem. This is cooperation and collaboration.

Also in the specification writing, we sometimes helped to write the specification of the transformer because the risk management starts there. Because as you say, if the specification is wrong at the beginning, it's already a problem in terms of risk management.

AR John, do you have something to add?

JU Yes. I would like to go back to comments that Marco and Jeff made, where Jeff said they have components six months supply ahead of time for their customers. And Marco said a lot of times, transformers are held up because bushings aren't being delivered. Going back several years ago, we were at the mercy of the purchasing agents. And they knew six months, nine months, a year down the road that these transformers were going to be built, but they ordered the bushings at the last minute. Obviously, it held up the production of a large transformer. I wouldn't say that we were educating the purchasing agents, but we were collaborating with them saying, “okay, you know ahead of time what you need. Give us a little bit more purchasing forecast.” And conversely, once we were able to determine their demand, we were able, obviously, to bring supplies in to meet those demands. In the past we might be handed a purchase order, take it or leave it. Now we are even collaborating with these same purchasing agents.

AR Let’s talk about failure modes. What are the failure modes that we're seeing as it relates to bushings?

JD Gaskets are an important common failure mode for bushings. It is something that I think we have handled very well in identifying good quality materials and identifying the right materials for the application. UV is a concern more for certain materials than others but shielding the gaskets from UV becomes important.

Making sure they are suited to the temperature that they're going to be operating at and with some new materials, we must know where we're pushing insulation temperatures. You must do the same thing with the gaskets. There are materials available to increase those temperatures. Some come with a hefty price, others more reasonable. But you must select the one that can hit those high temperatures, but also not sacrifice on the low side as well. A

lot of these transformers are stored in very cold temperatures before they are put into service. You can have those cold temperatures affect the gasket from the start, creating a loss of life before the transformer is even put into service.

AR Marco, you've seen a lot of them. You mentioned the failure. You see the potential, like that one bushing you're talking about, that you could determine from that what the failure might be for the other bushings. Talk a little bit about from the high voltage side failure modes.

MT On the high voltage side, the faults have a mechanical, thermal or dielectric nature. When they ultimately fail, they fail dielectrically. Apart from situations where you might have a bad connection on the top of the bushing, low oil, or worn gaskets, the internal failures typically are from two situations: one is the dielectric failure due to the short circuit between internal layers, the other is contamination of the insulation. The contamination can be, like in that case we mentioned before, from particles coming from external environment during the manufacturing process, or can be contamination due to moisture, which maybe is the most common failure mode for oil impregnated paper bushings. Moisture that enters from the gasket is very likely. Moisture enters, gets trapped in the paper, and then it migrates between the paper and oil, which means that sometimes you do the test, and the bushing is cold, and everything is fine. Then the bushing heats up during the summer season or because there is high load, the moisture gets out of the paper and the power factor changes, and you find the problem.

AR John, your thoughts?

JU To refer to some of the comments from Jeff and Marco, a common failure mode is due to thermal cycling. If you don't have the proper materials, with thermal cycling happening because of the various environments, whether you're far up north or near the equator. It could be any transformer during transport in use. It could be cycling from minus 40 degrees Celsius to 120 degrees Celsius several times. If the bushing cannot stand that amount of cycling it has to do with coefficient of thermal expansion, coefficient of thermal conductivity, then you can have cracking.

We have also found microcracks during installation. And in some cases, the installers aren't following proper protocol, putting, in some cases, induced stresses on the bushings. You don't necessarily see those microcracks until they are installed and in use. Suddenly, you have electrical failures, unfortunately.

One other problem we've seen in the field at times is that there could be leakage going between the interface of the conductor and the epoxy itself. Where you have leakage there could be aggressive contamination going back into the transformer, so the transformer becomes compromised.

AR Let's back to the collaboration part that we talked about earlier, and while this question is for all three of you, it is particularly for John and Jeff, as suppliers to the transformer market. What would you tell a young transformer design engineer some of the most critical things for them to consider when specifying bushings for transformers are? Let's start with you on that one, Jeff.

JD Well, I feel like we've touched on some of these points already, but those would be the loading of the bushing and possible overloading, and what margins are being allowed depending on the type of bushing construction. With many of the resin types, they're not built for overloading. Some are, but you have to dig into it, see what material is used, what its capabilities are, and talk to the manufacturers. Same thing goes for gaskets. Even if the insulation itself can handle the overload conditions, even common industry standards allow for thermal short time currents. It can be 25 times operating current for a short duration, but it can also allow the bushing to reach temperatures where some damage, some loss of life of that gasket, can occur. So, gasket selection, whether it be for high temperature, low temperature, chemical compatibility, even UV, as you mentioned earlier, and ozone, are all very critical.

AR Okay, John, any thoughts?

JU For a young engineer, I would strongly recommend that they talk to people that have been in the field for a number of years, to get a feel for the theoretical and the practical. For instance, there is the theoretical amount of amperage that you can put through copper per square inch, and obviously, most transformer users are using them beyond their normal specifications or theoretical limit. They are overloading them. They're being used past their limits. And in most cases, they're doing quite well, so they were obviously over-engineered for their use. If anything, I would tell a young engineer to really pay attention to people who have been around and listen to the practical part of it as well.

AR Marco, what would you tell somebody who is designing a monitoring program for transformers, and they are asking you, what should I be looking for and at?

MT You must ask the right questions at the beginning before starting to do the design. What Jeff was saying about overloading is very important. In the practical case, we do overload calculations for transformers.

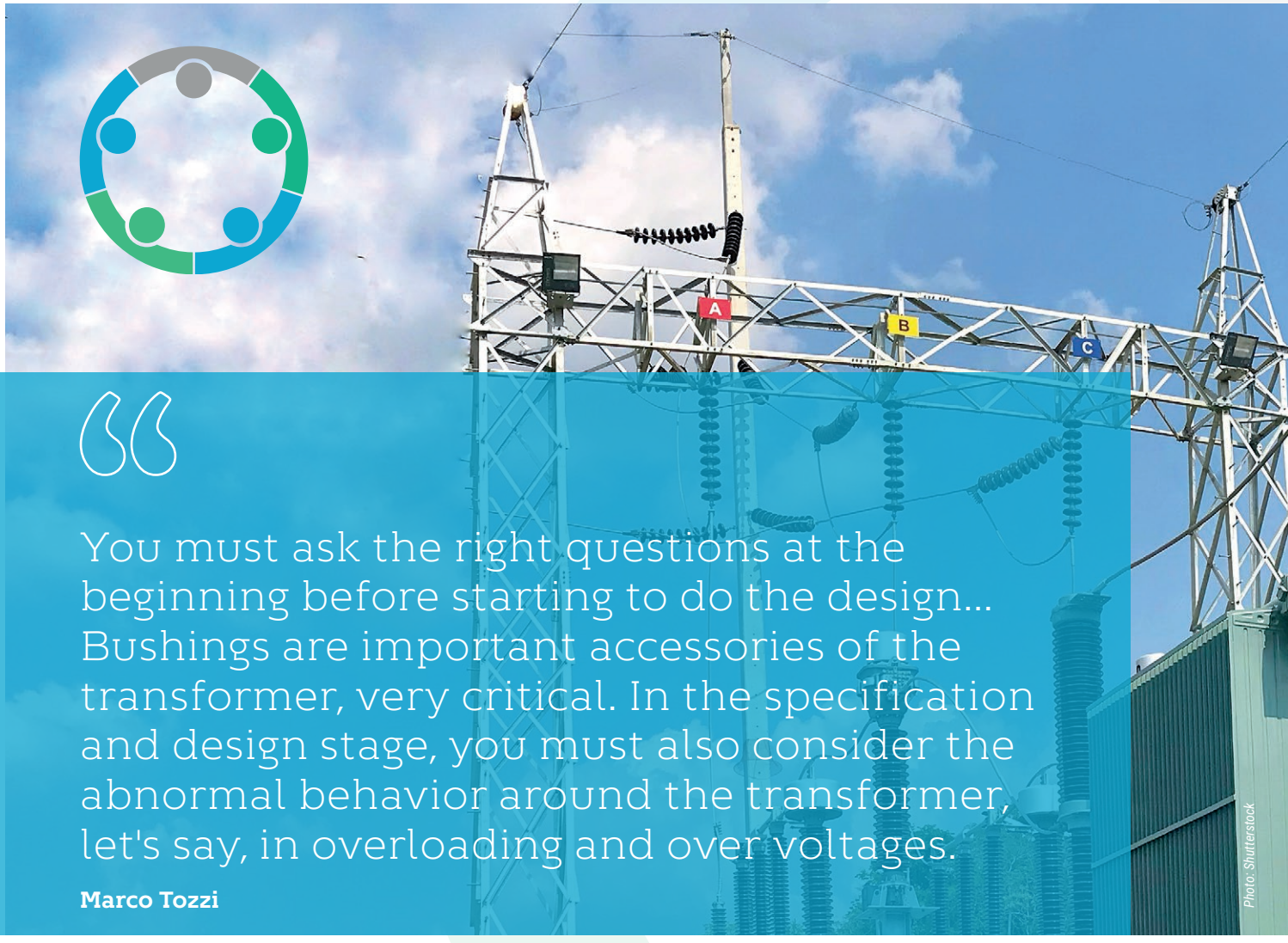
Sometimes you might not consider, for example, bushings and tap changer in your calculations because you are doing the calculations for the transformer. So, you look around the windings, the maximum current in the windings and so on. And you might forget that if you apply that current, you might be exceeding the maximum current of the bushings.

Bushings are important accessories of the transformer, very critical. In the specification and design stage, you must also consider the abnormal behavior around the transformer, let's say, in overloading and over voltages.

A recent theme is the fast-switching transients from GIS. This is something that is apparently causing some issues to some design of bushings, especially with resins. It is not like before, just designing the bushing based on voltage and current. You must also consider the environment where the transformer is s supposed to operate, from electrical phenomenon to pollution and corrosion and so on.

AR I was at a conference and one of the speakers, one of the panelists, was from Southern Cal Edison. He mentioned the fact that because of all the increased transients from renewables, particularly from solar and wind, that it is exacerbating the failure rate transformers. They are aging faster because of all these renewables. The idea that a lot of renewables that come online create a system that ages; have you found that to be the case? Because is it aging bushings more rapidly? Jeff?

JD It can be, certainly. I know reverse flow in transformers is a concern. But one thing is with the harmonics from the inverters that has been an issue now being addressed.



“You must ask the right questions at the beginning before starting to do the design... Bushings are important accessories of the transformer, very critical. In the specification and design stage, you must also consider the abnormal behavior around the transformer, let's say, in overloading and over voltages.

Marco Tozzi

Photo: Shutterstock

They are shielding the cores of the transformer to prevent the harmonics, through capacitive coupling, transferring through the core to the medium voltage side, where it was causing problems for bushings and connectors and cables, and the transformers themselves.

AR John, have you heard anything about this? I call it super aging of an existing infrastructure.

JU Like I mentioned before, we're just basically running the equipment hotter than it was intended for, and it is aging faster. Our customers, the OEMs, are developing transformers that are more robust, able to handle higher stresses. But again, that's still just meeting the current demand. We still haven't been able to catch up to the demand that is coming.

AR Marco, any thoughts on this?

MT I agree with what has been said. There is an impact. There are utilities that are taking countermeasures, for example, installing through-fault current monitors, devices that can understand what happens outside the transformer because their transformer was supposed to work in a certain way. Maybe they are facing 20 short circuits in the distribution grid or coming from other plants that are affecting the mechanical structure. Things are also changing to face this issue from renewables.

Also, in the renewable plant itself, they have quite a challenge because they don't have the same technical knowledge of historical electrical utilities and are operating the transformer in an unknown environment without the same level of support the utilities typically have, because everything is seen mainly from the financial point of view. The transformer is just a node in the cash flow to a certain extent. They are facing a lot of challenges with the main step up interconnect to the grid.

AR Last question gentlemen. Tell me a little about what your companies are

doing today as it relates to serving the industry? Jeff, we will start with you and H-J Family of Companies?

JD Well, we are busy, with a lot going on, a lot of growth. In terms of our manufacturing, our epoxy molding operation, we see tremendous growth. We have several materials, not as many as Crosslink, I can tell you that, but the materials we have developed here, our chemical engineering director formulates the resins in-house, and we run them through rigorous testing. We are optimizing our formulas for use in our process on our components with our equipment. That has worked very well for us.

Recently, for our APG process, we added a larger press than we have ever had before. The platen size is three times, so we're able to mold larger components right now. Our largest ever, several hundred pounds, multiple copper conductors encapsulated in epoxy.

As for the development of other products for power transformers, we have nitrogen blanketing systems for oil preservation and as I mentioned before, some new epoxy bushings for pole mount transformers. We are doing a lot of work with higher temperature epoxies for them to work with our bushings, low and medium voltage, to hit the 130C and 155C temperature ranges. We have a high voltage laboratory, where we're rigorously testing all of that.

We have hundreds of years in design experience combined. We have a lot of people who have worked in the industry for decades, working for us full-time and we have some who are now semi-retired and work for us as consultants. They are absolutely a great help to us.

AR Thank you, Jeff. John, talk about Crosslink Technologies.

JU I consider myself a techie. I love the technology part of it. So that is what I am going to talk about. We consider ourselves to be very innovative. Everything we do, we try to be customizable to the customer. We do projects that other people don't want to do, or think it takes too much time. We like to customize to the to the engineer's needs. Our philosophy is not to make our specific customer's company successful, but to actually make the engineer look successful. He or she comes up with a need and we make the design. It becomes very successful. He becomes successful within his own company. And he looks good. The company looks good. They have a good product. That is where we're looking, even within that concept of innovation.

We're also doing that internally so that we can turn parts around faster. Again, lead times are always a big issue with customers. We're finding ways of lowering our lead times, keeping quality and delivery at 100 %.

It is really, in our case, very much a partnering thing. We obviously have electrical engineers. We have mechanical engineers on staff that are there to support our customers. We customize the designs and the processes to meet our customers' needs.

AR Excellent. Thank you, John. Marco, you get to talk a little bit about Camlin Energy and that part of Camlin Energy is part of a bigger thing, Camlin Group, correct?

MT Yes, correct. The Camlin Group has the Camlin Energy division, where we work with the utilities and operators in the energy sector. Our mission is really to establish trusted partnership with customers. And that's why we moved from selling the sensors like we did even 20 years ago into now the software and the services, because we see this need to assist the customer, especially industrial and renewable customers. Indeed, the combination of sensors, services and software is critically important for these smaller customers who really need this partnership, which is, by the way, a means to learn every day. It's a mutual learning.

This is the mission of Camlin Energy. We are really operating in this direction, to create this partnership. That is why in US now, we are expanding with facilities and offices in order to stay closer to customers . In Italy also we have now a big operation. So, depending on the market needs, we are expanding to stay close to the customer.

AR The next generation is desperately going to be dependent upon exactly what each of you've talked about, collaboration, communication, educating them, because the next generation of engineer doesn't want to make a mistake, as you said, John, you make the engineer look good, right? The idea that all three of your companies are customer-centric, which means they are people-centric, which means you are engineering-centric, which is the biggest transition that is taking place within the power industry right now is that we are teaching the next generation of engineers who specify, who manage, who monitor, and who make decisions about the grid, everything they need to know to make good decisions.

Thank you, gentlemen, for being part of that, for your time, energy and expertise.

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