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TRANSFORMER TECHNOLOGY MAG



SUBSTATION SOLUTIONS

SPECIAL SUPPLEMENT INSIDE

PST POWER SYSTEMS TECHNOLOGY

Technology Insights: **Transformer Reliability by Design**
The Ins and Outs of Circuit Breaker Monitoring: Interview with **Chris Rutledge**, Dynamic Ratings
Metal Enclosed Electrical Bus - **The Lifeline to the Transformer**

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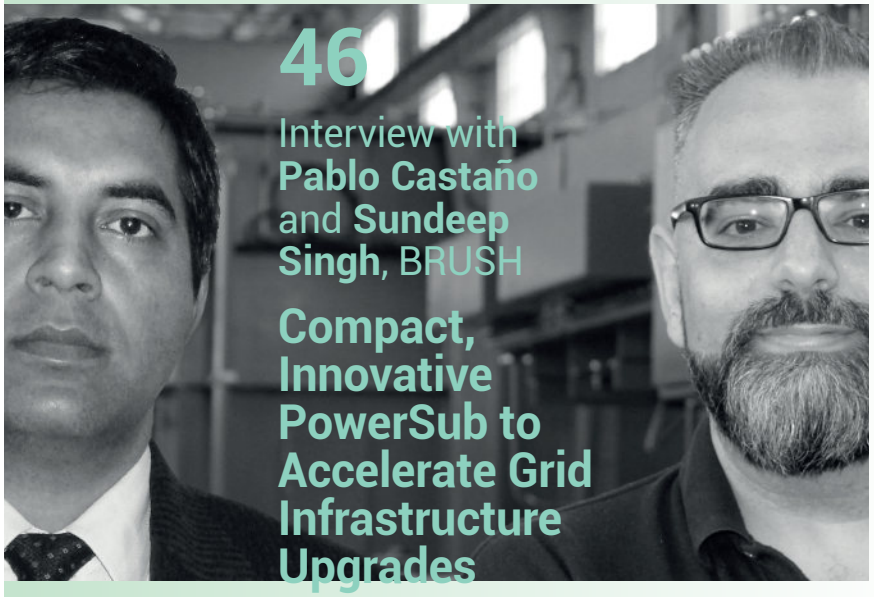
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Reliable transformers are the result of a proven design, qualified manufacturing process and the right choice of materials for the desired application. Our in-house transformer expert, Corné Dames, delves deeper into this subject in her latest article on transformer reliability.



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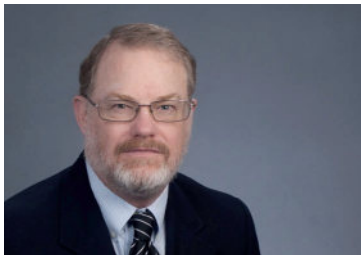
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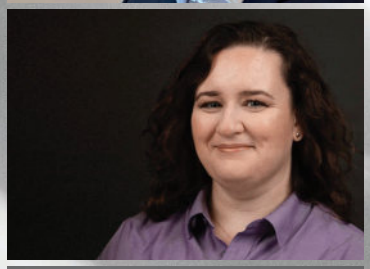
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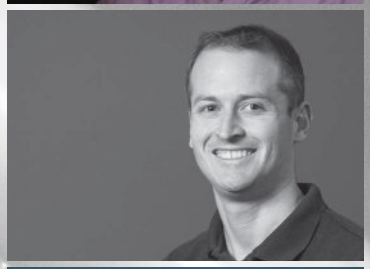
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Dear Readers,



One of the things I enjoy doing is planning strategically. That might sound like "consultant speak", but it reflects how I think - approaching editorial content from a purely strategic perspective. This issue of Transformer Technology (TT) is the result of a strategy that we developed months ago, but are now seeing it come to practical application. With the launch of Power Systems Technology (PST), we are entering a new and exciting time of change and growth.

The reason for my excitement with this issue in particular is that we have also added a feature column **Generations** and in its first appearance it features an article by Brenda Hite and Ben Lanz based on the life and work of Dr. Mathew Mashikian who *"grew up speaking Armenian to his parents, Arabic to childhood friends, French in school, and eventually mastering English at the collegiate level"*. I expect this column to become a regular feature within our content, where we are going to share the lives and stories of a generation of founders who have blazed trails in the technical foundations of our industry. Brenda and Ben provide insight into a man who is an inspiration to all who know him. Now you will get that chance to know him as well.

Why are you seeing more interviews, especially with this issue? It's because we want to allow Subject Matter Experts (SMEs) to share their expertise and their opinions about technology, the companies they lead or the dynamic change that is taking place in the power industry. Sharing the stories of these SMEs and their perspective on the future of technology in our industry is a personal passion of mine. The 39 interviews I was able to conduct at the April IEEE PES T&D event in New Orleans and that are featured on our website, only pointed that out more clearly to me. In fact, **if you know a leader within our industry who has inspired you or one who has laid the technical foundation for their company, please introduce them to us**.

Just as transformers are the heart of any electrical system, the rest of that system is critical to the modern resilient and reliable grid, so Power Systems Technology is a natural extension of the technology of the grid and in subsequent issues we will provide insight into the many aspects that make up PST, while staying true to our roots in Transformer Technology.

We consistently focus our digital magazines on content that practitioners need to know about current solutions to past and current problems, but also on future solutions to current and evolving problems. Personally, I see our body of knowledge as somewhat of a legacy that I would like to leave, one that future generations can access on subjects that matter.

Just as transformers are the heart of any electrical system, the rest of that system is critical to the modern resilient and reliable grid, so Power Systems Technology is a natural extension of the technology of the grid and in subsequent issues we will provide insight into the many aspects that make up PST, while staying true to our roots in Transformer Technology. In our daily news feeds we will publish content to both communities, with easy to access news and information.

Finally, upcoming issues will focus more on Transformers once again as we feature great content on Bushings and Solid-State Components in October, and Insulation, especially Oils & Fluids in December. Both issues are usually jam packed with great articles and interviews and once again this year, we are excited about the quality of our interviews and articles. **We still have a little room in December for the technical insights and developments within insulating systems for power system assets as well as transformers, should you have content you would like to suggest.**

As always, we are a community and we love to hear from you so we can "practitioner to practitioner" make our industry smarter, safer, more resilient and more reliable. Please contact me at alan.ross@apc.media with feedback or ideas for future content.



Alan M Ross
CRL, CMRP
Editor in Chief
APC Media
Technical Director



Chris Rutledge



DYNAMIC RATINGS

“

To maintain the breaker properly, you need to exercise those breakers every year. The longer a breaker just sits there, the more likely it is to fail.

Product Engineer
at Dynamic Ratings

Interview with **Chris Rutledge**

Photo: Dynamic Ratings

In this interview we talked to Chris Rutledge, the Product Manager of the Breaker Division of Dynamic Ratings. As we launch Power Systems Technology and look out for experts in different areas outside the transformer, Chris is a perfect person and an expert to talk to.



Alan Ross: Chris, I would like to call you our in-house expert on breakers, monitoring, maintenance, and all things breakers. Thank you for joining us.

Chris Rutledge: Thank you, Alan.

AR I am really passionate about the reliability of the system as opposed to the reliability of assets, because I'm a reliability guy. And the IEEE Reliability Society, which I'm a member of, focuses on components of an asset; they don't even focus on the assets in the system. I know that you find this familiar because you've been in the transformer industry and you understand transformers. You have worked for Memphis Light, Gas and Water (MLGW) and you've been around the industry as a practitioner. How long is your experience?

CR It spent about 27 and a half years at MLGW, and I am running close to three years at Dynamic Ratings now.

AR Let us first get down to basics here. One of the things that strikes me about you is that, like me, you are also someone who likes to look at the reliability of a system. But I want to talk specifically about breakers for a moment and the impact on transformers. When you are looking at breaker maintenance and monitoring, you are talking about backup in the system, etc. What do you think the negative impact is and in what way it could be positive?

CR It's really a huge thing if you think about your substation and just your general layout. Let's take a distribution substation, for example. We have a lot of feeder breakers that feed individual circuits going out to the customer. We have a bank breaker between the transformer and the feeders. So, if a feeder fails to clear a fault, that bank breaker is now going to operate and you're going to kill the whole bus. And then of course, we have our high-side breaker which is going to kill everything that is a fault and comes from the high-side or if that

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feeder fails to clear. And I've seen instances of all of this. I think what a lot of people fail to notice is the effect that those breakers are having on that transformer. When it comes down to it, you have your relaying but those breakers are your sole source of protection for that transformer. There is nothing else to interrupt a fault current coming through there except that breaker.



And I have seen in my career, I think, three failures associated with breakers that did not open.

If you have a low-side bus somewhere between a bank breaker and transformer, the high-side breaker fails to open and the breaker fail scheme doesn't work, you end up with six minutes off through fault on a transformer, which is a catastrophic failure every time. Not only that, but the amount of damage done to the station is large. When a fault hits the cable trays after it has burned all the grounds off, it burns the station house down too. So now, we can't bring that transformer back online, but we're also stuck with two other transformers we can't energize because we no longer have any control in the station. That's a worst-case scenario for breakers. What I've really been concentrating on lately, is helping people to understand how that scheme works. For instance, that feeder breaker sees that through fault, and let's say we're at three cycles for our feeders. That transformer immediately sees that fault as well. So, the whole time that fault is present, it's going through everything in that series circuit from that feeder. So, you are feeding it through the whole time.

When I was working with utility, I found that we had a lot of slow feeder breakers. Let's take for example first trip testing. For years we were going with offline timing and travel. You have to operate the breaker first to run that test. Here already you've lost a wealth of data as to how that breaker is going to perform once you do that first operation. But where you really get in trouble with, and the part that is getting overlooked by a lot of utilities I feel, is when that feeder breaker clears. You have some delay between the feeder breaker and the bank breaker. Let's say it is a 15 cycle, which means that that bank breaker has given that feeder breaker 15 cycles to clear that fault. Let's suppose we have a feeder breaker that clears in twelve cycles as opposed to three. That's four times the duration of fault current we should be seeing on that transformer every time that happens with that particular feeder. As that fault is going through that transformer, you have to understand that there's mechanical stress that is caused by the fault current. So, we've got radial and axial movement of those windings when that fault is going through. But the second thing you have to consider is the thermal stress that's placed on the transformer. So, the longer that feeder breaker takes to clear that fault, the worse that thermal stress gets, the hotter it gets. And that's exactly what you are doing to all your insulation systems and that transformer with that short being held longer than it should. So, you are destroying some of your solid insulation or excessive amounts of solid insulation every time this happens. That transformer is sent out of the factory with a certain amount of clamping force on that core coil. But that's dependent on the mass that you're clamping. So, as you are thermally degrading the cellulose insulation system, you're essentially taking some of the mass away from that core coil and now the clamping force isn't what it was when that transform was shipped out. As this goes on, over time you are losing clamping pressure, which is now allowing for more axial and radial movement every time we have a fault. This is why you see these small little through faults come through. And it's not an individual fault that fails the unit, it's the accumulation of all these faults and potentially these faults being held in place for too long that has weakened the clamping pressure to where it was no longer sufficient to hold the windings in place during that event.

It's not an individual fault that fails the unit, it's the accumulation of all the small faults that have been held in place for too long, weakening the clamping pressure to where it was no longer sufficient to hold the windings in place during that event.

AR That is incredible insight. The accumulative effect on something, especially a transformer in everything, especially heat. Transformers are all rated so that you can run it over for a certain period of time. But the longer you do that over a longer period of time, you are having to deal with heat that has another impact on cellulose and everything else. I never heard that about the clamping. I never thought about that. There is a great video by GE showing the transformer that just suddenly comes apart as a catastrophic failure from a lot of different little things.

So, you have given us the problem. What is the solution? Because I find very few people out there who are taking what I would consider to be robust best practices for breaker testing, maintenance, and monitoring.

CR I feel like a lot of that has got lost with the newer breakers, the vacuum breakers, and SF6. There really is less maintenance involved there. With the old OCB type, which I dealt with because 60% of our fleet was still OCB when I left the power company, there was an art to that. And I feel like some of that over the time has kind of gotten away from the utilities in general. Some of that expertise has moved out. You have breakers with low maintenance, so the training that's applied is not as intensive anymore. So, the biggest solution is to be able to track those through faults. And there are several ways that that can be done. We here at DR, we have several products that allow for this. We have our E3 products which actually have fault counting on it. So, you see the amplitude and duration of every fault that's gone through that transformer, and we also offer breaker monitoring. One of the important things about breakers that I really stress, is the importance of gathering a baseline of the waveform capture of the trip coil and face currents.

Those waveforms, the profiles of the coils, should overlay perfectly. There should be no more than two milliseconds of discrepancy. If you are seeing more than that, it means there are some lubrication issues going on, something's going wrong with that breaker and it is only going to become worse over time if it isn't addressed. The problem in many cases is that the breakers are just not operated that often. You need to go to the maintenance site and exercise those breakers every year. The longer a breaker just sits there, the more likely it is to fail.

When it comes to the statistics of breaker failures, around 80% of them are minor. Meaning, the breaker didn't open in time. With major failures, you're getting on up in the 90-percentile range of the failure being directly related to a mechanical portion of that breaker not functioning as it should. And out of those, from my experience, most of the time it will be a lubrication issue. In the breaker, there is grease which has a couple of components - the oil part, which could be mineral oil, or it could be a floor of silicone. That's your lubricant. And then there is a thickener, which is clay or soap that holds that lubricant in place. So, if that breaker sits there, and isn't operated for three or four years, over time, you start to get separation of these two components. That oil will leach out of that thickener, and what you're left with is just a gum-type substance in your breaker. This is why I moved to first trip testing as I was leaving the utility. Once we started doing that, I would see breakers that may take 400 milliseconds to open the first time and on the second operation, it would actually open in 30 milliseconds because by opening and closing it, you mix the grease back up and it's back where it should be. I would definitely recommend that you at least do a first trip every couple of years to get the real-life timing of that record.

In the breaker, there is grease which has a couple of components - the oil part and a thickener. If the breaker isn't operated for three or four years, over time, this will lead to separation of these two components.

Because you don't get a warm-up run on a fault. You don't get to exercise once and then try to clear it. The breaker has got to do its job the first time. And from all my experience, I can tell you that that first trip, can be just unbelievably long. And if you're taking that thing out of service to test it, you're missing a lot of data and don't even

Photo: Dreamstime



know that you have a problem. Now that we're doing monitoring, we're capturing data in a very similar way to this first trip with the waveform capture. And during the monitoring, we've had a couple of instances where a breaker was three milliseconds slow to open initially, and maybe two weeks later, it was six milliseconds slow, and then a month later it had a 20-millisecond delay. So that's something you really need to keep an eye on. And just exercising the breakers on a regular basis makes a huge difference.

Once we started first trip testing, I would see breakers that may take 400 milliseconds to open the first time open in 30 milliseconds on the second operation, because by opening and closing it, you mix the grease back up and it's back where it should be.

AR Let's talk about SF6 briefly. I know there is a new gas being developed to replace SF6. Why do SF6-free breakers require so much less? And don't they have the same mechanical issues?

CR They do, but they have fewer moving parts. SF6 is such a good insulator, you really don't have to have a lot of separation of contacts to interrupt that arc. With the old OC breaker, you are looking at about 12 inches of travel that that breaker was having to go through to actually have enough distance in those contacts to make an interruption. With these, it's interrupting in a fairly short throw.

AR Do you still monitor those?

CR Yes, we do. When it comes to monitoring, there are other things to take into consideration as well. There are things that get missed a lot in internal inspections or in routine inspections. For instance, when it comes to cyclic maintenance, you are doing your timing test and you will run a contact-resistance test of the breaker. Or take for example a pneumatic breaker. If you have leaks developing in that system, that motor could start 20 times a day. But I've seen instances, and I can't tell you how many times this has happened, where we were doing testing on a pneumatic breaker and had a motor burn up and we were constantly left

with one that won't operate. And that is why we monitor all of these different parts, including motors. At DR, we've actually divided motor starts up into a couple of groups just because of the different types of mechanisms. We have motor starts that are associated with breaker operations. And that would mean that if you have a spring-tight mechanism, you're going to expect a motor run on the close, and you shouldn't see any other motor starts associated with that breaker. If you start seeing extra starts after that, there is something wrong with your stored energy system or controls or something like that.



When you get into pneumatics and hydraulics, pneumatics have a design leak built into the system because you want that compressor to run once a day just to keep condensation out of the lines. So, when you have those separate motor runs that aren't associated with that breaker operating, we count those separately from the runs associated, and we set a limit on that. So, it's an excellent leak detector at that point. Because the average is one-two motor runs a day and if suddenly the average jumps to four or five, you've developed a leak in that system, and you need to get out there and take a look at it. That's something I actually learned after coming here. I had never considered how many times a breaker motor runs during the day when I was in utility because I wasn't sitting next to one 24 hours a day. But now that we have monitoring and we count these excessive starts, we immediately realize that we need to stay close and on top of it to see if it is a leak or if it's just a hydraulic system that has lost pressure because it got colder and it had to have a motor run. So, we track those differently to keep up with leaks in these systems, which extends your motor life on the breaker greatly, meaning that it is one less miss-operation you are going to have.

AR I have one last question for you, Chris, and this is an important one. When you think about monitoring, it creates information, creates data. There's a certain amount of data that you are tracking. A lot of what you are describing, though, is that somebody has to look at that data and make a decision to do something. In terms of the monitoring that Dynamic Ratings is doing, how do I, as an operator, depend upon you? Do you have to say to me, "Hey, look at the data!" or are there alarm systems? What makes it so that we don't fail to act?

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You've got to have a definite action plan in place. The way the breaker monitor is set up, all the data is coming out over the in-house tool that you have. I set interrupting time alarms very tight, so that a very small change is going to send you an alarm.

CR A lot of thought went into that actually, Alan. That was something I really stressed as an asset manager when I was with utility. You've got to have an action plan in place. It can't be, "Oh, we've got an alarm," and they just shut down the alarm because everything looked okay. And that happens more than you care to think it does. Or in the case of transformers, you get a hydrogen alarm, and the reaction is "Well, everything seems fine, just clear it." And nobody even checks to see if everything really is fine. You've got to have a definite action plan in place. The way the breaker monitor is set up, all the data is coming out over a SCADA. So this would be coming into an in-house tool that you have. I set interrupting time alarms very tight, like I said, so that a very small change is going to send you an alarm. Heater goes out, motor problems, any of these alarms, they will all come in over your SCADA system, at which point you will receive an alarm through whatever in-house software you are running. It's at that point that you can dial in to the breaker monitor over Ethernet. You can go in and pull the web page up and it allows for a comparison of the waveforms. And after looking at them, we can see whether it looks like a latch issue, or a main bearing issue, or a wiring issue. And these are all things you can identify readily from the waveform capture. As I mentioned before, you get a baseline when you first do this and then every operation after that, you can always compare to how that breaker was performing. And you are looking for changes. It is very similar to monitoring a transformer. You look for changes and you are checking to see if some component did something different. And then of course, you've got to have an action plan. The great thing about monitoring is that it allows whoever is observing the process to do some pretty good analysis as to whether a latch didn't come loose, or the main bearings took too long to get the contacts open. This in turn allows you to give your crews very specific instructions. When I was working at the utility, I learned that when you can give your maintenance crew specific instructions on where the issue is or what to look out for, you get far better results.

The great thing about monitoring is that it allows whoever is observing the process to do some pretty good analysis as to whether a latch didn't come loose, or the main bearings took too long to get the contacts open. This in turn allows you to give your crews very specific instructions on where the issue is or what to look out for, and when you can do that, you get far better results.

AR Chris, you are a wealth of knowledge. I am inviting you back again for phase two of this discussion because I really want to talk about that action part.

CR Yes, I would like that.

AR I would also like to make a point that there is a lack of people out in the marketplace who understand what you understand, because we've had a whole generational transfer of people leaving without the next group of people understanding what to do. So, we are going to have to give them a hand and let them know "Hey, when it says this, do this."

CR I agree, it has become almost like the Pass the Message game. You all whisper, and that's how knowledge gets passed down. It gets watered down as it goes, and eventually, it gets lost. No utility that I've ever been to really has a book that says what to do. It's just, well, this is out. And the attitude is often "Well, we've been doing it like this for 50 years." We rode horses at one time too and we upgraded that, so it might be time to upgrade our procedures a little bit too.

AR Chris thank you so much for joining us.

CR Thank you, Alan. It was great to be here.

Best Practices for HV Bushing Condition Assessment

by **Daniel Carreño**
Abel González Gómez
and **Volney Naranjo**



Introduction

Bushings are the means by which electric power passes to and from different electrical devices, as they provide a point of interface for electrical voltage to be applied and current to pass to and from an electrical apparatus. The bushing's main function of allowing the current to pass through the apparatus cannot be achieved without the bushing's ability to insulate the main conductor from ground.

Construction of bushings includes condenser and non-condenser types. Most high voltage bushings today are of the condenser oil impregnated paper (OIP) type. OIP type bushings are susceptible to failure due to aging, contamination and deterioration of its composite insulation system, therefore a non-intrusive and non-destructive testing technique capable to evaluate changes of the dielectric properties in the inner insulation of the bushing is vital for power system operators and manufacturers of HV equipment.

In general terms the tests that are performed on bushings during maintenance include conductor and connections integrity (low resistance measurements), infrared inspections –usually to determine the oil level of the bushings and insulations tests, including Power Factor (PF), capacitance measurements, Dielectric Frequency Response (DFR), and in some specific cases, Dissolved Gas Analysis (DGA) and Partial Discharge (PD).

This article covers exclusively best practices to carry out PF and capacitance tests on OIP type bushings.

Field tests of PF and capacitance of bushings are valuable techniques to assess the insulation integrity of a bushing, but, as described in this article, are susceptible to measurement errors due to external factors.

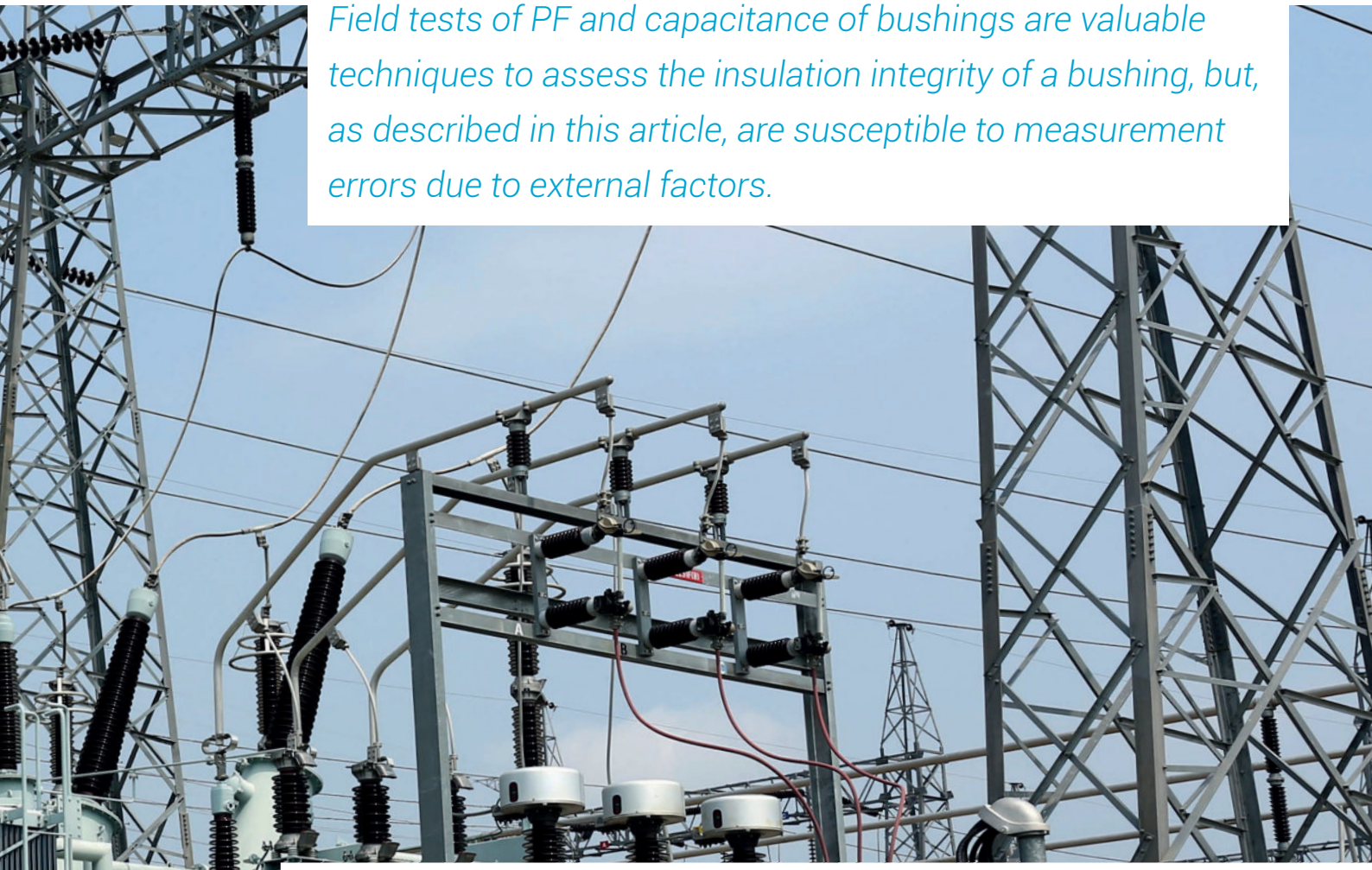


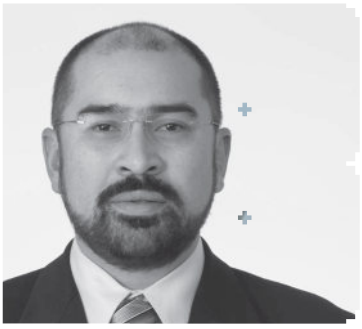
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Daniel Carreño is currently the Knowledge Base Product Owner in Megger. Prior to his current role, Daniel spent several years with Megger's Technical Support Group, as an Applications Engineer, specializing in transformers, batteries and high voltage circuit breakers testing. He graduated from Instituto Politécnico Nacional, in Mexico City, with a Bachelor of Science in Mechatronic Engineering. His previous experience includes working for power transformer manufacturers in both The United States of America and Mexico.



Abel González Gómez is a Senior Relay Applications Engineer with Megger. Received his bachelor's and his MSc in Electrical Engineering from the Universidad Central de Las Villas, Cuba in 1996 and 2000. From 1996 to 2000 Worked as an Assistant professor for the Faculty of Electrical Engineering at the Universidad Central de Las Villas, Cuba, from 2000 to 2010 as a Teletraffic Engineer, Control Engineer and Head of the Marketing Department for the Cuban Telecommunications Company and a professor of Marketing and Electrical Engineering, for the Universidad Central de Las Villas, Cuba. From 2010 to 2013 worked as a Design Engineer for Arteche Medicion y Tecnologia in Zapopan, Jalisco, Mexico and Curitiba, Brazil. From 2013 works as an applications Engineer for Megger, LTD in Markham, Ontario. His research areas are the analysis operation, control and protection of electric power systems. He is currently a member of IEEE-PSRC.



Volney Naranjo joined the Technical Support Group at Megger in 2011 as an Applications Engineer focusing on the products for transformer, low-voltage and high-voltage circuit breakers, batteries, and power quality testing. He participates in the IEEE Energy Storage and Stationary Battery committee and has published articles in conferences such as TechCon, PowerTest, TSDOS, BattCon, and EIC as well as technical magazines. Volney received his BSEE from Universidad del Valle in Cali, Colombia. After graduation, he worked in the areas of electrical design and testing and commissioning of power systems as a field engineer and project manager.

Power Factor Testing and Setups

OIP bushings are designed as a capacitive divider with many capacitors, grouped by a tap connection, in two main capacitances or as two capacitors C1 and C2, which values are usually indicated by the manufacturer on the bushing nameplate. The tap connection, depending on its constructive characteristic, is classified as a test tap or a voltage tap.

Lower voltage bushings do not require a tap and the capacitance, C, of a bushing without a voltage or test tap is the capacitance between the high voltage conductor and the mounting flange (ground).

The test is typically done at line frequency, at 10kV for C1, and 500-2000V for C2, or at the voltage suggested by the bushing manufacturer depending on the application. Before applying a test voltage to the tap, the maximum safe test voltage must be known and observed. Only the tap cover for the bushing to be tested should be removed.

For C1 measurements, the test is conducted in the UST test mode which eliminates the losses leaking to grounded portions of the bushing.

Measurements on C2 use GST-g test, energizing the tap and measuring the losses leaking from the tap to ground.

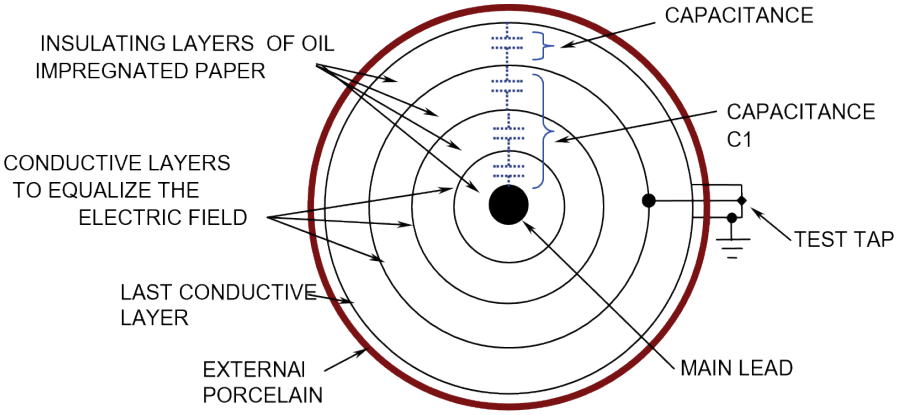


Figure 1. Modeling the OIP bushing as a set of capacitive layers

The C1 capacitance, is the main insulation of the bushing and is measured between the high-voltage conductor and the voltage tap or the test tap. The capacitance C2, is the insulation layer between the tap and mounting flange (ground), and it is regularly shorted during normal operation or connected to a potential measurement device for online monitoring or as auxiliary power. If there is no tap, the PF testing is performed using the hot collar technique, described hereinafter.

PF and capacitance measurements of C1 and C2 are performed sharing the same test setup: all the bushings of each side (voltage level of the transformer) should be isolated and shorted. All groups of untested bushings should be grounded.

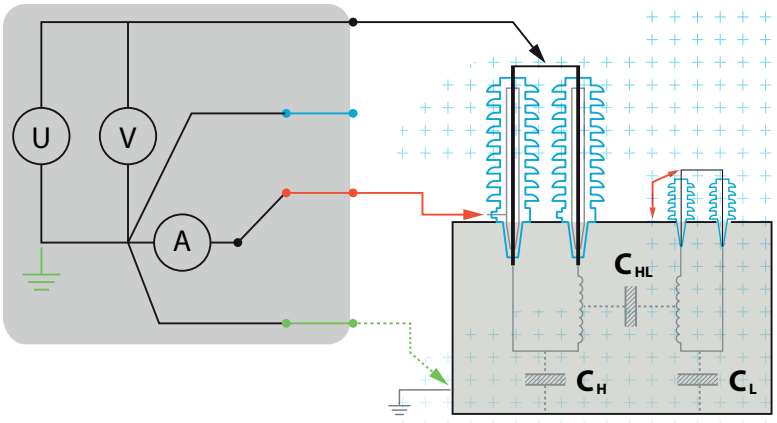


Figure 2. Setup for C1 power factor and capacitance measurement using UST-R test mode

This measurement is not appreciably affected by connections to the bushing center conductor.

For bushings not equipped with either a test tap or a voltage tap, the main field measurement which can be performed is the hot collar test which generates localized high-voltage stresses through the various sections of any bushing or pothead, so the dielectric losses can be measured. This is accomplished by applying the voltage to a conductive collar band designed to fit closely to the porcelain surface, usually directly under the top petticoat. The bushing center conductor is grounded by connecting it to the red cable and using the GST-GND test mode, which measures the overall losses leaking to both, the center conductor and ground.

The test provides a measurement of the losses in the section directly beneath the collar and is especially effective in detecting conditions such as voids in compound filled bushings or moisture penetration since the insulation can be subjected to a higher voltage gradient than can be obtained with the normal bushing tests.

Following the best practices outlined in this article will help an individual to either find the cause of an abnormal reading or to ensure those results are an indication of a deteriorated insulation system, or an actual failure.

Analysis of PF & Capacitance Results

The evaluation of the results of power factor measurements is done by comparison with standard defined limits or trending of historic values. Such limits are different depending on the type of bushing and are defined at a specific test voltages and frequency. Table 1 shows the accepted IEEEC57.19.01 and IEC 60137 standard limits for PF values for OIP bushings. Typical values for new bushings range between 0.2 and 0.4%

A change of the PF can indicate problems such as moisture ingress, degradation, carbonized parts or bad contacts. According to CIGRE 445 a doubling of the initial PF value warrants either more frequent monitoring or replacement.

A change in capacitance could indicate a breakdown between capacitive layers. An increase of 10% in the value of capacitance from the nameplate value could warrant replacement of the bushing.

IEEE C57.19.100 indicates that any bushing exhibiting progressive increase of PF values should be considered for investigation and potential removal from service. The guide also states that some bushing manufacturers consider an increase between 1.5 and 2 times the initial reading to be significant. Therefore, it is good practice to address a progressive increase of PF values with the manufacturer. Regarding capacitance, the guide considers an increase in capacitance of 5% or more over the initial/nameplate value to be cause of investigation.

Field Challenges

Testing in the field brings a number of challenges and it is not uncommon to obtain unexpected results. Typically, the first suspect is the test instrument. One common troubleshooting technique, if there is any doubt about the PF test set, is to perform an open-air test, which is commonly described in the user manual of the instrument and includes expected results. An additional test to verify the instrument is to measure a reference capacitor.

Once the test set has been verified and confirmed its optimal operation, the next step is to verify the test modes utilized in PF testing: UST, GST-g, and GST-GND.

Finally, the field is not always an ideal place for testing and external factors influencing the measurements must be considered, especially: temperature, moisture, contamination, and handling of the tap.

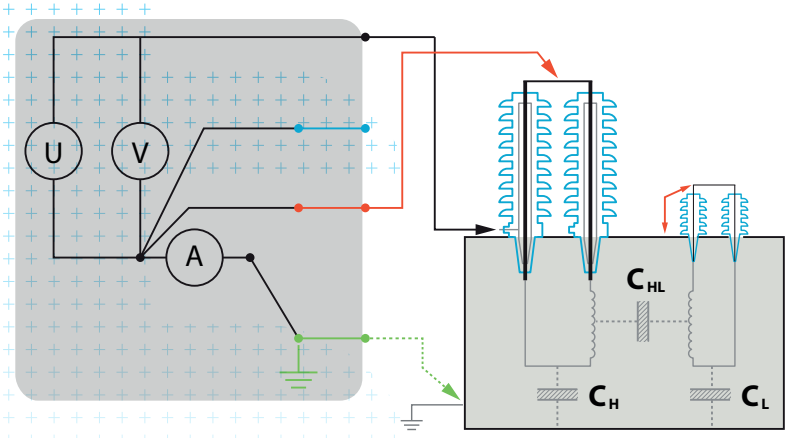


Figure 3. Setup for C2 power factor and capacitance measurement using GST-g test mode

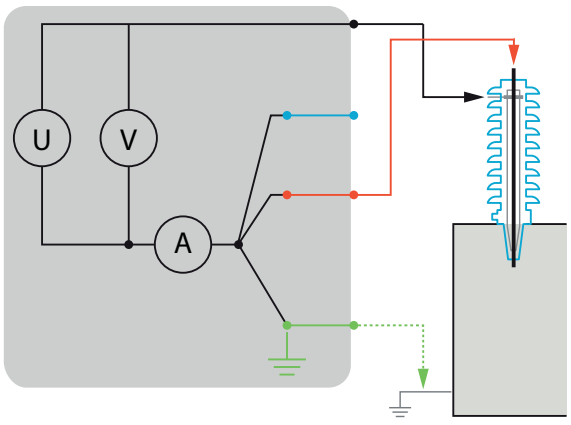


Figure 4. Setup for hot collar measurement using GST-GND test mode

REFERENCE	Test Voltage	Maximum acceptance PF/DF value %	Temperature (°C)
IEC 60137	1.05*Um/(1.73) and Um	0.7	10 to 40
IEEE C57.19.01	Typically 10 kV for C1	0.5	Corrected to 20°C

Table 1. International standards PF acceptance limits



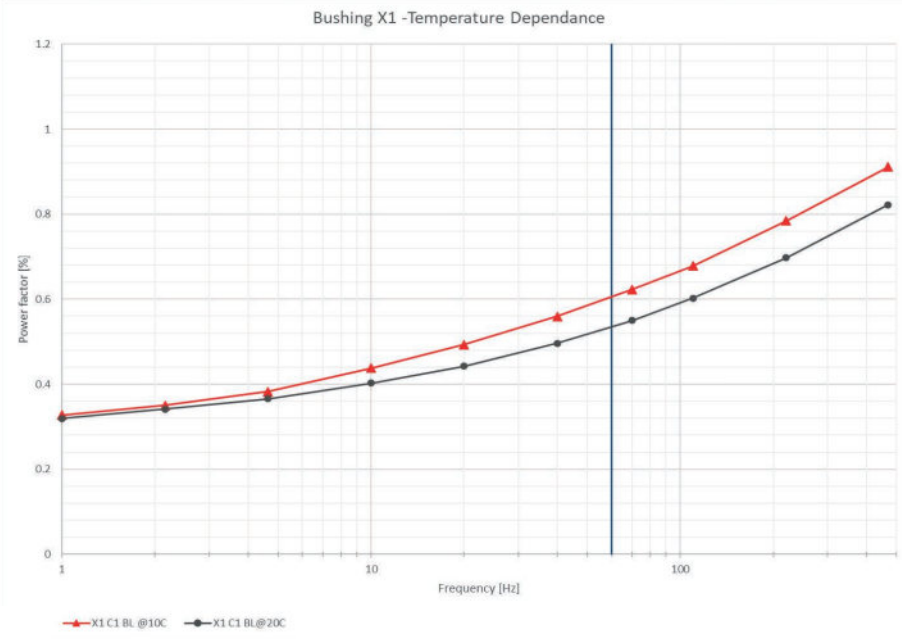


Figure 5. Example of bushing PF temperature dependence

Estimating the Temperature of the Bushing

Although PF measurements are obtained from accurate instruments, results need to be corrected to 20°C for trending analysis and comparison against nameplate data. Temperature correction is highly dependent on insulating material and its structure, ageing condition, presence of moisture or contamination, so that a fixed correction factor from a reference table may introduce some error in the corrected value by over or undercompensating. An alternate correction method is the Individual Temperature Compensation (ITC), which calculates an accurate correction factor based on a variable frequency PF measurement and

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Another important source of measurements error is the temperature dependency of PF, which can be accurately corrected using the ITC method.



the fact that a power factor at a certain temperature and frequency corresponds to a measurement made at different temperature and frequency.

Despite the method, proper determination of the bushing temperature is required to avoid introducing a higher error in the corrected value. Since there is no direct measurement of the bushing temperature, it must be estimated, and the recommended approach is calculating the average from the transformer top oil temperature and the ambient temperature.

It is common practice to consider 0°C (32°F) to be the lowest temperature acceptable for testing. Dielectric testing has been performed below this value, but special attention must be given to the results obtained. It is always recommended to discuss results with the manufacturer.

Temperature correction factors for specimens at high temperatures (above 40°C) may be limited by the reference tables; however, ITC provides accurate correction of C1 PF at a wide range of temperatures, even greater than 55°C.

Correct Handling of the Capacitance Tap for C1 and C2 Measurements

In a capacitance graded bushing, the test tap is a component which main purpose is to provide access to measure the bushing capacitance and power factor. The voltage tap, in addition, can be used for permanent voltage measurement or online monitoring of PF or partial discharge.

When testing the bushings of a transformer, it is advised that all bushing tap caps remain installed (closed), except for the bushing or bushings under test. Since the test voltage is applied to a group of bushings, any unused test tap will have a potential difference if not grounded; the voltages that can be developed at open test taps may generate leakage current that not only can affect the PF results but severely damage a bushing and pose a safety hazard for the individuals performing the tests.

Special care should also be observed to properly connect the test leads to the capacitance tap, as in some cases, adapters are needed to be able to achieve a suitable connection while maintaining isolation from ground. These adapters are usually provided by the test set and/or bushing manufacturer.

In addition to that, make sure that the tap is properly connected, and it is not loose.

Effective Grounding and Shorting Techniques

When performing power factor and capacitance measurements on bushings of a transformer—both single and three-phase—it is a well known practice to short all the bushings of the same group (same voltage level) together, to form an equipotential section of the transformer with each winding group when performing a test. See shorts (a) an (b) in Figure 6.

In addition to the safety factors involving shorting and grounding groups of bushings during power factor and capacitance measurements, these connections will also be useful when facing situations involving surrounding energized overhead lines and equipment, which can cause unwanted induced voltages. These voltages, in conjunction with the winding inductance of the transformer, and the stray capacitance between the windings and the bushings insulation, can lead to measurement errors.

Hot collar application

A hot collar test generates a localized high-voltage stress by using and energizing a conductive collar around the porcelain, which is useful to determine the dielectric losses (Watts and current, as PF is not analyzed) through various sections of any bushing when troubleshooting high PF results. It is useful to detect cracked porcelain, deteriorated

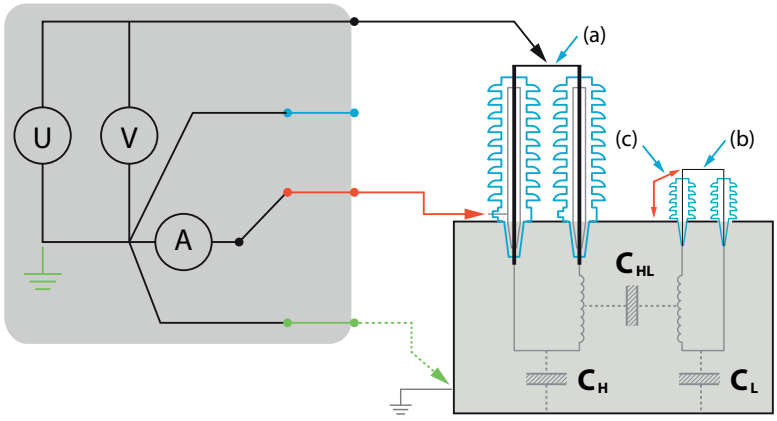
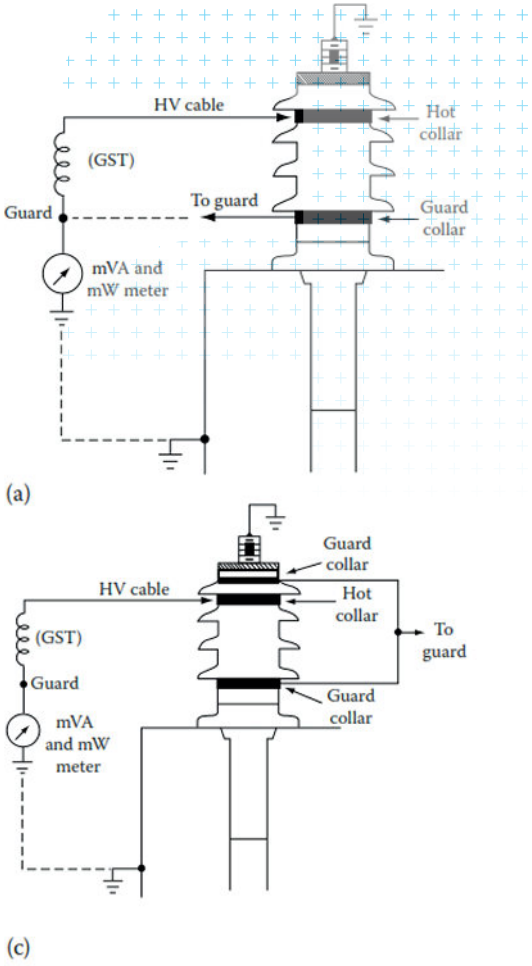


Figure 6. Effective shorting and grounding techniques



Hot collar test can be performed with any of the test modes, GST, GST-g, and UST, and using one or multiple collars depending on what is expected to achieve with the troubleshooting, as per the images below, from the book, Electrical Power Equipment Maintenance and Testing by Paul Gill.

In a given test, when the test voltage is applied, all bushing of that group will be at the same potential with respect to ground due to the short between them. On groups of bushings untested, a second auxiliary connection to ground is necessary, (Figure 6, connection (c)), to avoid floating potentials to be developed on such bushings, which, just as open test taps, can be hazardous for the persons taking the measurements.

cement joints, gasket leaks, or faults within condenser layers in condenser-type bushings and to check the oil level of oil-filled bushings when normal oil level readings has been stablished or comparing to bushings of the same type. If an abnormal mA or Watts reading is obtained when the test is performed at under the top petticoat, the test should be repeated at under the second petticoat and move further down until finding normal readings.

The general guidelines to evaluate hot collar data are as follows:

- Watts Loss
  - <100 mW - Acceptable
  - ≥100 mW - Unacceptable, possible contamination
- Current
  - Within 10% of similar bushings - Acceptable
  - <10% of similar bushings - Unacceptable, low level of liquid or compound, possible faults within condenser layers

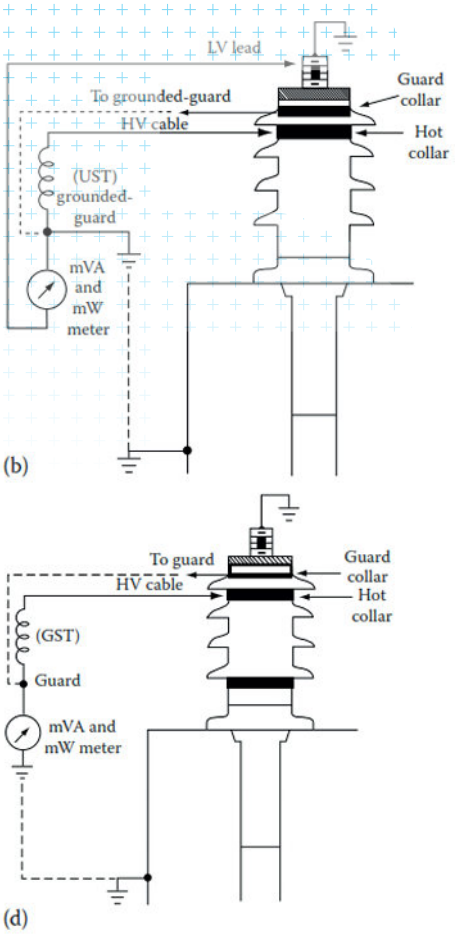


Figure 7. Hot collar test setup in: (a) GST mode; (b) UST mode; (c) guard mode, guard above and below; and (d) guard mode, guard above

NBDFR, an Alternative Technique for Results Validation

It is common with PF results that after troubleshooting, the result is still not satisfactory, it is slightly high compared to the reference values or the trend, and the main conclusion is to investigate further. The Narrow Band Dielectric Frequency Response (NBDFR) technique is an alternative method to troubleshoot and investigate inconclusive PF results. It consists of multiple PF tests at different frequencies in a range of 1 to 500 Hz. Incipient or emerging changes of the resistive losses at 60 Hz PF are too small in comparison to the capacitive component, which is proportional to the frequency, of the total current.

The example in Figure 8, illustrates a case of four LV bushings exposed to the same loading/thermal profile and environment. The 60 Hz results are below 0.5% and almost identical, the evaluation of this result will not trigger any investigation or action. The NBDFR result shows that X3 has higher losses, yet unnoticeable at 60 Hz; enabling an individual to decide on proper remedial actions.

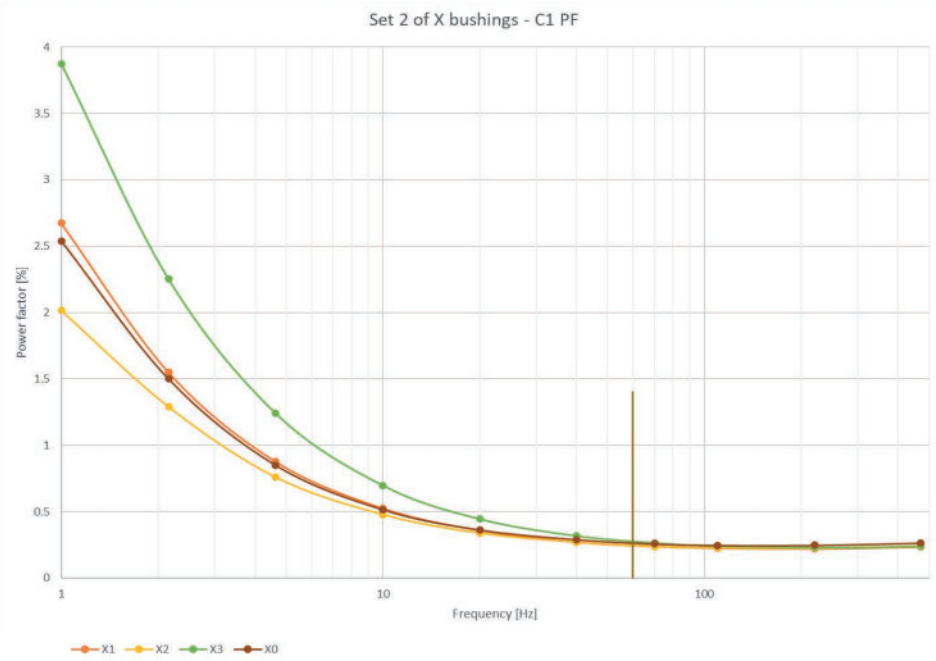


Figure 8. NBDFR on four OIP bushings



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Alternative test procedures such as NBDFR measurements, provide extra information about the condition of the insulation system, thus enabling the user to make a deeper and more informed analysis of the results.



Conclusion

Field tests of PF and capacitance of bushings are demonstrated to be very valuable to assess the insulation integrity of a bushing, but, as described in this article, are susceptible to measurement errors due to external factors. Following the best practices outlined in the previous paragraphs, will help an individual to either find the cause of an abnormal reading or to ensure those results are an indication of a deteriorated insulation system, or an actual failure. Another important source of measurements error is the temperature dependency of PF, which can be accurately corrected using the ITC method. Additionally, alternative test procedures such as NBDFR measurements, provide extra information about the condition of the insulation system, thus enabling the user to make a deeper and more informed analysis of the results.

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Corné Dames is the Managing Director of Independent Transformer Consultants, always striving to keep on top of new developments and research. She has expertise as Laboratory Manager in the analysis of transformer oils and as diagnostician identifying problem areas in transformers, as well as profiling of transformers according to available results thus empowering the customer to take preventative steps in maintenance. Corné has vast practical and theoretical knowledge on reliability maintenance programs. Coming from a strong chemical background she has insight in all the chemical processes that are part of the transformer system. Coupled with technical insight, her knowledge and experience help customers optimize their reliability maintenance and electrical asset lifetime.

ESIGN

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Introduction

Power transformer is the highest cost item in a substation, and a critical piece of equipment at every stage of electricity transmission from a power plant to the end-user. While transformers are significant to electric grids, transformer failures are common and costly. There are many causes of failure: insulation failures, design/manufacture errors, oil contamination, overloading, power line surge, loose connections, moisture, and other artificial or natural causes.

Since transformers are the key components in electric grids in terms of reliability and investment, the reliability of transformers is a primary concern to grid operators. Transformer reliability models are crucial for electric grid design, assessment and operation.

Much research has been done on the reliability of transformers. A condition-based evaluation method was presented to assess the lifetime status of power equipment [1]. This method, developed by ABB Group, is a unit-oriented approach that identifies the most vulnerable units in a population by ranking them according to specific rules. Decision-making on appropriate actions is based on this ranking. Two critical factors that are part of the model to perform a life assessment of transformer insulation in power plants are ambient temperature and load on the unit [2].

Van Schijndel, Wouters, and Wetzer [3] proposed a policy to determine the reliability of a whole transformer population from individual transformer reliabilities by estimating the life expectancies of individual components.

Lower cost choices may lead to more expensive maintenance or loss of equipment at the end of the day. Ensuring equipment suitable for the application and environment is vital for prolonged service and reliability.

Transformer design consists of essential components used to compile the end-product. But a variation in each of these components will deliver a unique transformer with a set application at the end of the design and manufacturing process. Each of these components will chemically and electrically interact within the transformer system. In collaboration with environmental factors, these interactive processes will determine the transformer's end of life and maintenance.

Reliability and lifetime optimization are the main goals for the plant manager. The cost of a short outage is phenomenal. Therefore, failure would be a tremendous cost to the owner when the total cost of ownership is calculated.

Reliable transformers are the result of a proven design, qualified manufacturing process and the right choice of materials for the desired application.



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Global reliability surveys indicate that reliability is heavily dependent on excellent quality bushings, tap changers, and the active part. Only the highest quality will suffice – no compromise can be made on these components.

What is failure?

Any unscheduled situation which requires the equipment to be removed from service for investigation, remedial work, or replacement is a failure. This can be divided into minor and major failures, both with forced and scheduled outages.

Major failure

Any situation which requires the equipment to be removed from service for a period longer than seven days for investigation and remedial work usually requires the transformer to be removed from its plinth and returned to the factory. Also, a reliable indication that the condition of the transformer prevents a safe operation should be counted as a major failure if work of more than seven days is required to restore the original service capability.

Minor failure

This type of failure requires remedial work that lasts less than seven days.

Component choices

Some key components in the manufacture of transformers are bushings, tap changers, insulation materials, and active parts.

A power transformer must withstand tremendous loads during its lifetime. This requires quality down to the smallest detail and carefully selected components. Global reliability surveys indicate that reliability is heavily dependent on excellent quality bushings, tap changers, and the active part. Only the highest quality will suffice; no compromise can be made on these components. First-class certified suppliers ensure the continuous supply of high-quality materials – even during periods of raw material shortage.

"Factory acceptance testing and compliance specifications can't guarantee longevity. One of the best indicators of a design's robustness is short circuit testing of designs and looking at the history of tests from the same design system," it is cited in a white paper by ABB [4].

Specifications have evolved to address changing customer requirements and expectations. This evolution has brought about its own set of challenges; as a result, most specifications don't do as good a job as anticipated. They do not ensure a failproof system to guarantee the desired transformer life.

A common misstep in specification creation is simply adding to past specs, rather than looking critically at the actual performance requirements. It makes more sense to understand the application and requirements, and then design to the material limits while maintaining sufficient margins, than increasing margins unnecessarily. The power grid has evolved over the last few decades – it is more interconnected, with more sources and destinations. This leads to more issues with frequencies and more opportunities for electrical disturbances, the most significant source of failures for transformers and other transmission devices. The point is to include items in the specifications that will influence the unit's longevity.

With all this said, without an efficient maintenance program, the best transformer may fall short of the proposed lifetime expectation. Even if you buy the best vehicle on the market, you can be sure to have problems without the correct application and maintenance.

So, we can argue how much of the reliability is dependent on the design, how much on the application and environment, and how much on the maintenance.

The role of standards

The tightest, best-written specification can't guarantee a 40-year transformer life. The critical issue is the manufacturer's ability to produce a transformer that fully complies with the specification and the buyer's expectations.

Thirty years ago, the customer would personally qualify the facility and a team of auditors would evaluate every function in the factory. The buyer must rely on the manufacturer's quality documentation and standardized systems like ISO. They require documentation of the manufacturers' quality system and plan, inspection and hold points. The buyer wants to understand how quality is assured in the manufacturing facility and during all the processes. That is a critical requirement.

While it provides an excellent foundation to rely on national and international standards for a specification, they don't cover the exceptional cases or specific parameters the customer may need, even for the active parts of the transformer.

Once in service, there are factors that might impact the life of a transformer. The buyer needs to conduct appropriate maintenance. Is the load within the specifications for the unit? Are there significant variations in the load on the unit? Will there be frequent and intense disturbances?

All of this said, it still gives the buyer peace of mind to buy from a proven manufacturer with a recognized quality system in place.

A common misstep in specification creation is simply adding to past specs, rather than looking critically at the actual performance requirements. It makes more sense to understand the application and requirements, and then design to the material limits while maintaining sufficient margins, than increasing margins unnecessarily.

Selection of transformer fluids and comparison of characteristics to ensure optimum application suitability

The fluid in a transformer directly affects the operation and reliability of the transformer's components. The cooling capability and the unit's reliability depend on the fluid type and quality.

In the transformer industry, we have a choice of three basic fluid types: mineral, silicone and ester fluids.

Fire safety performance

Insulating fluids in transformers are used to cool down the transformer. Where there is heat, there is also the risk of fire. Fires in areas where many people move through or stay might be disastrous. Therefore, fire safety performance of transformer fluids is essential.

1. Fire danger grade comparison

The ignition point for silicone fluid was found to be the highest [5], see Table 1.

Parameter	Test Method	Mineral Oil	Silicone liquid	Synthetic ester fluid
Flashpoint	ISO 2719	150°C	260°C	260°C
Ignition point	ISO 2512	170°C	>350°C	316°C
Fire danger grade	IEC 61039	0	K3	K3

Table 1. Fire performance comparison results [5]





2. Ignition-resistant properties comparison
The ignition point of mineral oil is much lower than that of synthetic ester fluids.

Additional third-party fire certification for the synthetic ester fluid include:
1. UL fire certification – Underwriters laboratory – EOUV Dielectric Medium Classification
2. Factory Mutual Global – FM approved less-flammable transformer fluid
3. SGS BASEEFA, UK – ATEX Certification (Use authentication in potentially explosive atmospheres)

Thus, the higher fire safety performance of transformer fluid can significantly improve the safety performance of various transformer applications.

The tightest, best-written specification can't guarantee a 40-year transformer life. The critical issue is the manufacturer's ability to produce a transformer that fully complies with the specification and the buyer's expectations.

Environmental performance

Biodegradability comparison
Biodegradation is when the matter is decomposed and broken down into harmless components, bio-available to the environment, and incorporated into the ecological cycle.

Synthetic esters are non-toxic and biodegradable. The degradation percentage of synthetic esters are 10% by day three, 71% by day ten, and 89% by day 28.

The biodegradation of both mineral oil and silicone oil is less than 10% by the end of the 28-day test period in the study [5].

Risk of water pollution comparison
Umwelt Bundes Amt (UBA) assesses chemicals and divides levels based on biodegradability and the potential impact on aquatic organisms; the synthetic ester is classified as non-hazardous to water environments. Even at levels of 1000 mg/l of water, synthetic esters won't cause harm to aquatic systems. Mineral and silicone oil are classified as hazardous to water. In the case of pollution with mineral or silicone oil, the environmental pollution effects would be severe, and this would last for years.

Reliability
The main components of the transformer are immersed in the insulating fluid. The reliability of the fluid directly impacts the reliability of the transformer.

The transformer fluid might reduce the failure rate of the transformer components. The moisture resistance and oxidation stability might possibly reflect the reliability.

Moisture resistance comparison
When the moisture content of a dielectric fluid increases, the performance of the fluid will be affected. Increased water concentration will decrease the dielectric strength of the fluid.

The breakdown voltage and the water content of synthetic ester, mineral oil, and silicone fluid were compared under laboratory conditions [5]. It was found that the water content in mineral oil and silicone oil is very low; the breakdown voltage decreases rapidly when the water content increases. In contrast to this, the natural water content of synthetic esters is much higher than for the other oils; even when the amount of water increased dramatically (more than 600 ppm), the synthetic ester maintains a high breakdown voltage (more than 75 kV).

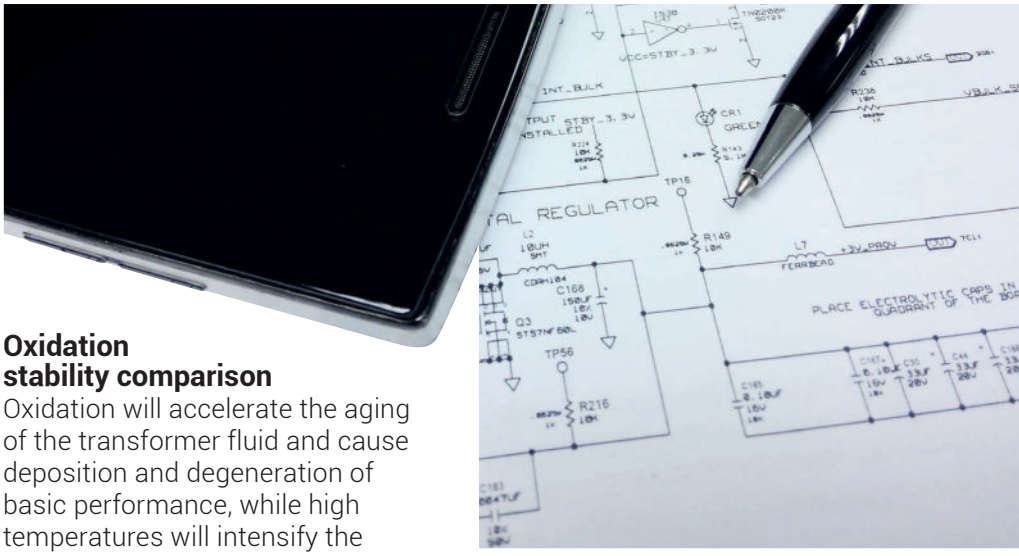
The increase in water content will cause accelerated aging of the insulation paper system.

Various studies show that the insulating paper aging rate directly relates to the water content. The increase in the water content of the cellulose paper by 1% reduces the life of the insulating paper by 10%. When cellulose ages, it will release water, aggravating the aging process. The excellent water absorption capacity of synthetic esters will reduce the water content, which will slow down the aging process of the insulating paper.

DES



Photo: Shutterstock



Oxidation stability comparison

Oxidation will accelerate the aging of the transformer fluid and cause deposition and degeneration of basic performance, while high temperatures will intensify the oxidation process. In the tests conducted, it was found that the oxidation stability of synthetic esters is high; however, the oxidation stability for mineral oil and silicone fluids was relatively poor [5].

Aging resistance comparison

The acidity is a crucial indicator of transformer fluid aging. In the study, it was found that synthetic ester did not produce corrosive sulfur or other sediments during aging experiments.

The power grid has evolved over the last few decades – it is more interconnected, with more sources and destinations. This leads to more issues with frequencies and more opportunities for electrical disturbances, the most significant source of failures for transformers and other transmission devices.

Conclusion

The average failure rate is described in a CIGRE survey [6]. In most cases, the faults in tap changers, bushings, and winding-related faults are the most significant causes of failures, while the solid insulation, together with liquid insulation, determines the transformer's life.

Knowledge of material science is indispensable in the transformer business. Reliable transformers are the result of a proven design, qualified manufacturing process and the right choice of materials for the desired application. Further developments in transformer design should be strongly related to the possibilities and limits of transformer materials.

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DIGITIZATION TURNAROUND

With its ISM® platform, MR offers transformer manufacturers an open platform for transformer digitization and supports them in becoming solution providers.



Photo: MR

Electricity grid operators are in the midst of a turning point: To ensure the stability of grids, they have to master complex modernizations of technology and infrastructure, for which intelligent transformers play a central role. To enable transformer manufacturers to meet these growing demands, MR now offers the ISM® platform which is an open, manufacturer-independent key technology for digitizing power transformers in which all data collected via sensors converges and which includes a freely configurable control system. In addition to monitoring individual transformers, important information for fleet control can be generated from the bundled evaluation across the entire fleet, thus allowing asset managers to perform condition-based maintenance, for example.

Proudly presenting the first transformer digitalized with the ISM® platform from the production of GANZ Transformers (from left): Gábor Farkas and Jan Prins as well as the representatives of Reinhausen Herbert Schubert, Sebastian Hilmer and Totmarton Balazs.

Advising the integration and development of additional services

The ISM® system is housed in a control cabinet in which all applications and functions are integrated, and all the data from the various installed sensor units converge. At the same time, the system serves as an open platform on which additional sensors can be connected in an uncomplicated manner, regardless of the manufacturer. As part of this new offering, MR also provides transformer manufacturers advice and support in developing their individual configurations. Once all technical and design specifications have been defined, MR produces the complete system in its own plant in Regensburg and delivers it just-in-time.

Jürgen Ach, Director of Automation at MR explains: "We can help transformer manufacturers transform themselves from system integrators to solution providers while becoming less dependent on subsystem suppliers such as sensor manufacturers. That's why we don't offer individual components but rather an open, manufacturer-independent platform on which they can compose their own solutions. This open principle means that we also install sensors from third-party manufacturers for OEMs. We also support them in developing their own software modules on the ISM® platform thereby enabling them to differentiate themselves from their competitors with an individual range of products and services."

Sebastian Hilmer, Head of OEM Cooperations, adds: "With the increasing demands on the energy grid as well as the growing amount of available sensor data, the need for intelligent algorithms is also growing. We develop these together with our customers and support them in opening up new business models - such as linking temperature and weather data to create an intelligent fan control system." OEMs save time and money by integrating all sensor technology and functions on one platform and by being able to add their own software to the system independently. Jürgen Ach adds, "A digital transformer is nevertheless a high cost factor. We want to be the ones to scale this concept - which means ensuring more affordable prices through high volumes - so that all OEMs can invest in digital systems."



Photo: MR

Hungarian manufacturer relies on MR's ISM® platform for its GANZ Intelligent Solutions

GANZ Transformers and Electric Rotating Machines Ltd. and Maschinenfabrik Reinhausen (MR) entered into a cooperation agreement in April 2022 for the development and production of intelligent transformers. As a Hungarian pioneer in transformer technology, GANZ is thus positioning itself as a digital solution provider and will consistently rely on MR's proven digitalization platform in the future. The aim of the cooperation is for both sides to become market leaders in regard to the manufacture of more efficient and sustainable transformers. Jan Prins, CEO at GANZ, says: "for new transformers, we are experiencing an increasing demand for sensors and evaluation systems. The collaboration with MR is therefore the first step for GANZ to develop a complete portfolio of smart solutions for all products and offer our customers the benefits of digitized transformers. In the medium term, we therefore not only want to be a system integrator, but also to offer our customers superior automation and digitization solutions."

OEMs can save time and money through the integration of all sensors and functions on a single platform and the ability to add their own software to the system.

ISM® platform

Based on the ISM® platform, which combines all of the know-how that MR has accumulated over the decades, manufacturers can easily integrate any sensors or software. All available data thus flow together via fiber optics into the central ISM® computing unit, where they are evaluated and assessed by means of algorithms. Depending on requirements, six different software modules are available, and the computing center, sensors, connections and cabling are all integrated in the control cabinet, thereby avoiding the need for several separate control cabinets and enabling the retrofit of additional modular functions. The ISM® platform thus creates the basis for networked transformers.

Maschinenfabrik Reinhausen GmbH

Regensburg-based Maschinenfabrik Reinhausen GmbH (MR) is successfully active in global niches of electrical power engineering with 45 subsidiaries and 4 associated companies, and 50% of the electricity generated worldwide is regulated by MR products. Founded in 1868, the company is majority family-owned in the fifth generation. In the past fiscal year, 3,500 employees generated sales of 750 million euros. Known as the innovative inventor of the on-load tap-changer, Maschinenfabrik Reinhausen has introduced the ISM® platform and developed ETOS®, the first open operating system for power transformers.





PST

POWER SYSTEMS TECHNOLOGY

SPECIAL SUPPLEMENT

Sundeep Singh



> “As part of a project with Western Power Distribution, BRUSH has developed an innovative plug-and-play substation solution that is a unique offering on the marketplace with many applications.

PHOTO: BRUSH

Pablo Castaño

BRUSH
TRUST. WELL EARNED.



Interview with **Pablo Castaño**
Product Manager for Transformers at BRUSH

and **Sundeep Singh**
Product Manager for Switchgear at BRUSH

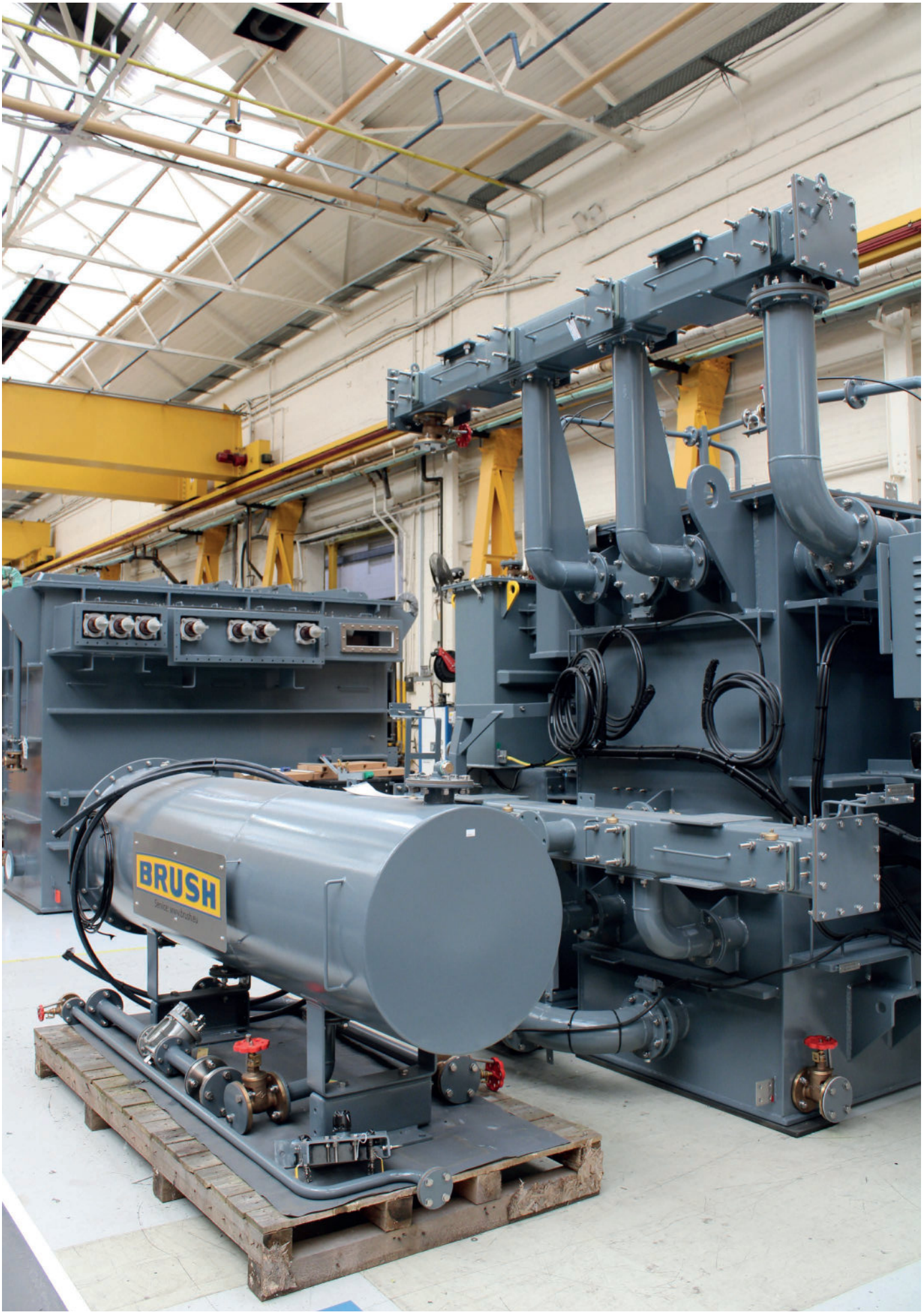


Photo: BRUSH

In this interview we hosted Pablo Castaño, Product Manager for Transformers, and Sundeep Singh, Product Manager for Switchgear from BRUSH, a power transformer manufacturer and service provider that has been around for over a hundred years. But our guests are talking about the future and a unique new offering that BRUSH is bringing out, which we happen to think is going to change the landscape.

Alan Ross: The new solution that we mentioned in the introduction is heavily needed. But before we go into what that product offering is and what it means to the marketplace, let me first say thank you for joining me, Pablo and Sundeep.

Pablo Castano: Thank you, Alan.

Sundeep Singh: It's great to be here.

AR BRUSH is a company that has been around a long time in this industry, and it was named after a man called Brush. A lot of people in the industry are not aware of this and they think a brush is some sort of component in an electrical system. Pablo, could you tell us a little bit about the history of the company?

PC The company was founded 146 years ago by Charles Francis Brush. He came over from your side of the Atlantic, and he purchased the site from an old carriage company and started setting up with generators and motors and eventually moving to switchgear, transformers, and so on.

AR 146 years create a pedigree. What are some of the values that BRUSH company brings to the marketplace?

SS The most important thing we offer is quality. Quality of product is at par compared to anybody else in the market. Another example is that we found a BRUSH transformer which was installed in 1938 and is still working, still providing electricity to the to a site in Nottingham. So, you can imagine that the kind of products we offer are built to last and theylast for, I won't say forever, but for a very long time.

AR 1938? That's one of the older transformers. What size is it?

PC It's a small 750 kVA distribution transformer, but it's 90 years old.

AR That is a true testament to quality. It's also a testament to great engineering. We believe that you have to engineer quality and that reliability happens by design. You have to design reliability into a product. I would like to talk about the products that you have developed. But before we go into the mobile substations that you've developed, I want to ask a question. What is the problem in the industry that you are trying to solve?

SS One is that the industry is trying to move towards net zero which includes the automotive sector. Secondly, the UK government has announced that after 2030, there won't be any new petrol or diesel engine cars on the market. This means the market needs to move quickly to an alternate source of power. And right now, electric vehicles are the most preferred option and they are the ones that are booming in the market. This in turn brings a lot of challenges for the power distribution industry because the grid is not designed to provide that much power. If we are talking about the concept of charging, let's say there are 200 cars on a toll station at a time, that is the same amount of power needed for a small town. In order to make that possible, a lot of investment and infrastructure upgrading are required and that's where we come into the picture by designing a product that can feed that demand.

Electric vehicles are booming in the market, which brings a lot of challenges for the power distribution industry because the grid is not designed to provide that much power. If there are 200 cars charging on a toll station at a time, that is the same amount of power needed for a small town.

The challenge was to design a product that is a plug-and-play solution that can be quickly installed. We created an innovative containerized solution that we can put on the back of our trailer and mobilize it, and within a couple of days it's up and running on the site.

AR I was reading about challenges that the utilities in the United States along the coast where we get hurricanes face. The last two major hurricanes in New Orleans completely knocked their power out. Trying to get the substations back up and running after such a catastrophe is a process that takes weeks, not days. So, the need for mobile substations when you have a weather event is enormous. Purchasing mobile substations for backup, resiliency and reliability for the network is another reason. So, we have the growth of EV, and we have weather events that are causing a need for a lot of change. Is there anything you would like to add to that?

SS Another challenge that utilities face, especially in the coastal area, is that during the holiday season they suddenly get a lot of tourists and if everybody needs to charge their car, there won't be enough power available. So that would be an alternate or additional requirement for a mobile substation to cater for the demand during the peak season which could be two, three or five months, depending on the weather and season.

AR In California, for example, there is a scramble because the state has been very aggressive in terms of what percentage of the cars being sold will be EVs. California has been the most forceful about it in the United States and as a result of that, they are going to have to develop new infrastructure to keep up. And what you at BRUSH are building is infrastructure. Right now in the United States, I think we are spending 4.3 billion dollars every year for the next ten years to build infrastructure in the grid, which is something we've never done on a national scale before.

Let me move on to the product itself. Obviously, it took time to develop it, and I believe the reliability starts with design. Could you talk a little bit about the product development process?

SS The challenge was to design a product that is a kind of plug-and-play solution that can be quickly installed. If you go with a traditional design, it could take up to six to eight weeks or maybe longer to install a substation, subject to planning, approval and all other permissions and products are available. So, the challenge was to design something which can be used quickly. That was our starting point. Then WPD, engineers and BRUSH designers worked together to create an innovative containerized solution.

We put that box on the back of our trailer and mobilize it, and within a couple of days it's up and running on the site.

AR I love plug-and-play. Drive it up, plug it in, and film at eleven, as we say here. Pablo. I know you are doing a project with Western Power Distribution in the UK. Could you talk about how the parameters of that project were designed, the timing and what you expect to happen?

PC The project came via Western Power Distribution, one of the utility DNOs here in the UK, or, to be more precise, it came through the market regulator for the UK, Ofgem. They have what they call the Network Innovation Allowance, which allows for the production of novel designs, new approaches to new problems, or new challenges. And this EV charging project on motorway services was an ideal candidate for that application. The project was registered in mid-2020 and we delivered the substation to the first site, which is in the southwest of England, in Exeter, to one of the motorway services about three weeks ago. The project is not concluded, but it was executed already. The next step will be gathering feedback from Western Power and from Ofgem. In terms of the solution, it is a good fit-for-purpose solution as well as being economical, efficient, and cost-effective. I really do believe we checked every box.

We just delivered the substation to the first site as part of the EV charging project on motorway services. In terms of the solution, this substation is a good fit-for-purpose solution as well as being economical, efficient, and cost-effective.

Photo: BRUSH, Shutterstock




GT4

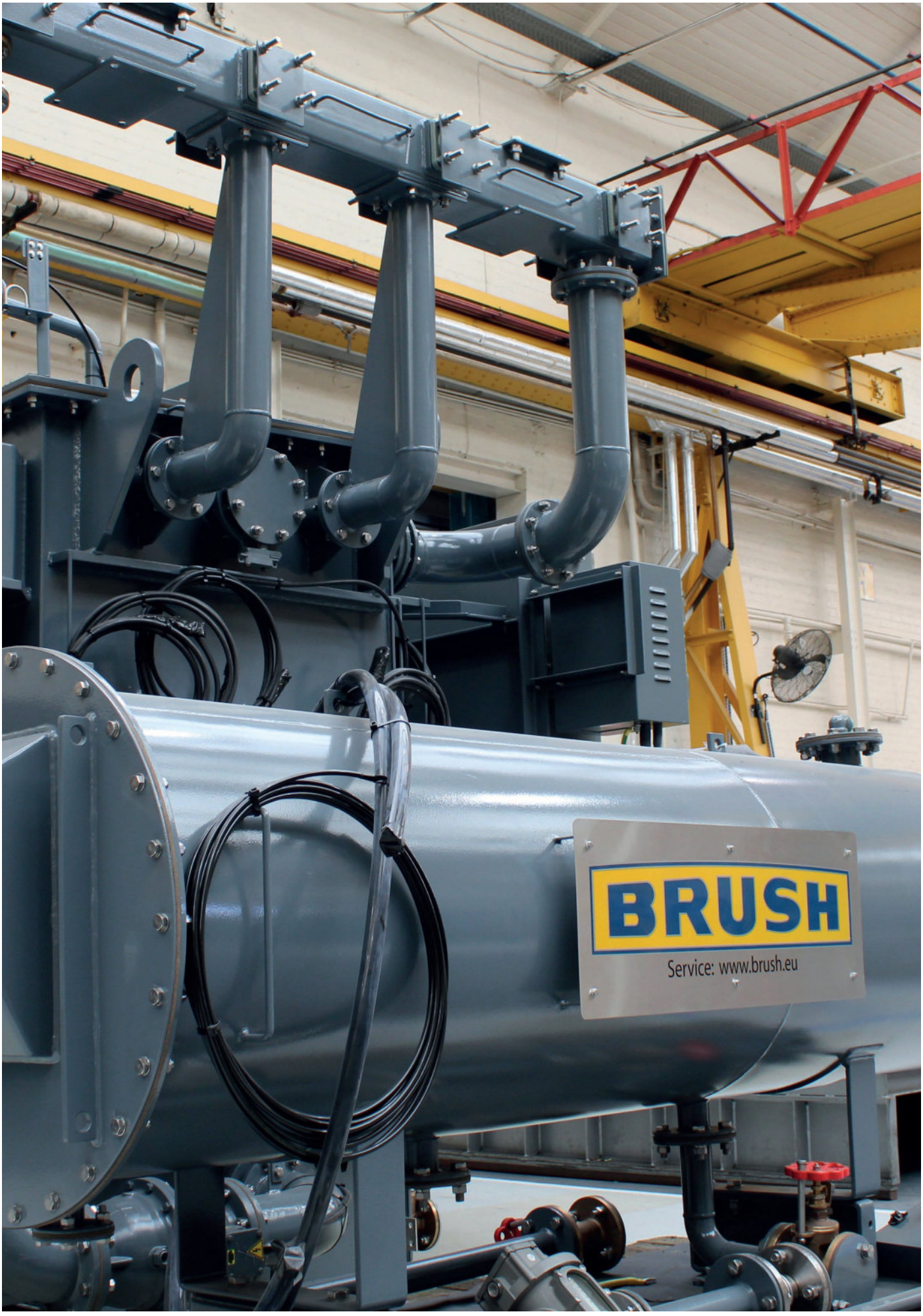


Photo: BRUSH

AR So, you created a solution, and now you are implementing the solution with them to test it. When does it go to scale? When do you expect BRUSH to suddenly go to scale in that area and maybe scale in the UK and in the US?

PC Well, it should be soon. The reason for that bold statement is that if we put into perspective the ambition of the plans of the government to effectively ban the sale of the internal combustion engine in less than eight years, the transformation required on the infrastructure has to be dramatic. It has to be radical even. In order to do that, adding and implementing this sort of solution has to be really quick. There are already so many issues.

AR I have a feeling that a company that is 149 years old has probably figured out a way to scale to get it to what it needs to be.

PC Oh, there is no problem with the scale we have got already. Currently, the solution goes from seven MVA to 20 MVA. However, making it even bigger, up to 40 MVA with the transformer is absolutely no issue. And the limitation in terms of available technologies has to do with the maximum available current for the switchgear. I believe the limit sits in around 45 MVA equivalent, which produces around 4,000 amps in terms of maximum amperage. So, scaling up to that size is no problem because it's just making the transformer bigger effectively and we can do that.

AR Are there challenges to this scale-up? What are they? Because going from 2 MVA to 40 MVA is a pretty broad range.

SS That's the scaling up of the capacity. But if you are talking about scaling up the volume of the business compared to us, a small country, we have approximately 4,800 motorway petrol stations. And literally, at some point in time, each and every station would need a solution like this to charge electric vehicles. So, we see that the demand will grow and will grow very quickly. As Pablo mentioned, by 2030 internal combustion engine vehicles will be limited and electric vehicles will begin to dominate. That means that in the next three to five years' time, I would say it is going to be a good problem to have, but yes, we would be struggling to keep up with that amount.

AR Why did you go for a mobile solution when it's a permanent solution that you need?

PC It's more to do with the compactness and quick deployment. Usually when you have what we call a primary substation, it takes a lot of paperwork and permissions and complications around the land, and the amount of available space is very limited. Next to a motorway with this type of solution, you get both sides of the switchgear into one compact container and then again optimize and reduce the footprint of the transformer. With the plug-and-play principle, you can simply drop the substation in there and walk away. This makes it simple and cost-effective.

SS Another advantage, as you mentioned Alan, is the bad weather factor. If a substation is damaged because of the weather, a lightning strike, or similar, the repair could take a long time. So, with this solution, if anything were to happen to it that was beyond repair or would take a very long time to repair, you can just take the container out, put the new one in and the lights are on again.

AR Incredible. I think you have developed an amazing solution. There are going to be other applications, for instance, cities where you can't get a substation in. You are going to need something smaller, easier to get in. I never thought about the idea that for damaged or aging equipment you need a replacement sometimes. Right now, the standard for some of the lead times has gone up to five years for transformers. How are you going to meet demand considering the supply chain and the labor issues we are all facing? Because I think you're going to be very successful with this product.

PC I hope we will be able to. We have plenty of capacity on the site if need be and plan to increase it as well.

AR This is going to be fascinating because I know that there's so much change going on in the marketplace right now and we need new solutions.

We will follow your projects and get updates to see how things are going. I want to thank you both for joining us.

Plug-and-play mobile substation is a solution that can be applied at EV charging stations, used as a backup for a damaged substation after a catastrophic weather event, used to create a more reliable power supply in tourist areas, and in city environments that require small and compact solutions.

Generations: From Persecution to Innovations in Field Cable Testing

by **Brenda Hite**
and **Ben Lanz**





Stories about trailblazers who change an industry and make significant contributions to technology to better humanity are seldom simple. Mashikian's story is no exception.



Brenda Hite is a Strategic Communications Specialist for IMCORP. She is a technology evangelist who passionately supports industry electrification efforts through education about technical, financial, logistical, and societal benefits of using cutting edge diagnostics to increase power system resilience, reliability, and safety while lowering costs. Before joining IMCORP, Brenda was the Membership Engagement and Services Manager for EPRA (The Electric Power Reliability Alliance), where she supported a growing and collaborative community of commercial and industrial electric power safety and reliability practitioners. She began her career as a Project Manager in the environmental consulting industry.



With over 25 years in the power and energy industry, **Ben Lanz** is currently responsible for IMCORP's technical education and outreach efforts and is the Chairman of the Board for the Power Delivery Intelligence Initiative (PDI2.org), a nonprofit organization dedicated to disseminating T&D best practices. He is a Senior Member of IEEE PES and ICC, and an active or voting member of IEEE DEIS and IAS, American Clean Power, CIGRE, NETA, and a founding member of Electric Power Reliability Alliance. He has served as Chair of IEEE technical committees associated with power system reliability, protection, and testing. He has published dozens of peer reviewed papers and technical conference contributions on the subjects of power system reliability, asset management and diagnostics and is frequently a guest speaker at numerous conferences and seminars.

Have you ever asked yourself "What makes a trailblazer? What prompts a person or company to think far enough outside the box, have a vision beyond the obstacles directly in front of them, and then actually manifest their ideas?" Meet IMCORP founder, Dr. Matthew Mashikian.

Born in Turkey in 1933 to an Armenian family who fled persecution to Lebanon, Mashikian grew up speaking Armenian to his parents, Arabic to childhood friends, French in school, and eventually mastering English at the collegiate level. From an early age, he learned to consider his audience, to overcome challenges and adapt to find success in his surroundings. After graduating from high school in 1950, he remained in Beirut and taught high school math for three years to help support his family. Mashikian went on from teaching to complete his Bachelor of Engineering degree at the American University of Beirut.

Both Dr. Mashikian and his future German wife's families fled persecution in their home countries, and through a series of moves and events they met in the early 1960s while he waited for a United States work visa and worked in Sweden for ASEA (the 'A' in modern day ABB) as a surge arrester application engineer. Eventually they both immigrated to the United States and settled in Michigan where Mashikian met up with the rest of his family and worked for Detroit Edison (modern day DTE) for sixteen years.

Dr. Mashikian, who fled persecution in his home country, waited for a United States work visa and worked in Sweden for ASEA (the 'A' in modern day ABB) as a surge arrester application engineer, before immigrating to the United States and settling in Michigan where he worked for Detroit Edison (modern day DTE) for sixteen years.



While at Detroit Edison, Mashikian developed patents in the areas of arresters, cable accessories, batteries, and electric vehicles, and helped support the development of the Electric Power Research Institute (EPRI), through which he collaborated with many professionals in the industry. During that time, he also went to school nights to earn his master's degree (Wayne State University), get his professional engineering license, and receive a Doctor of Engineering degree (University of Detroit) in electrical engineering.

Mashikian at Detroit Edison in early 1970s

While at Detroit Edison, Mashikian developed patents in the areas of arresters, cable accessories, batteries, and electric vehicles, and helped support the development of the Electric Power Research Institute (EPRI).

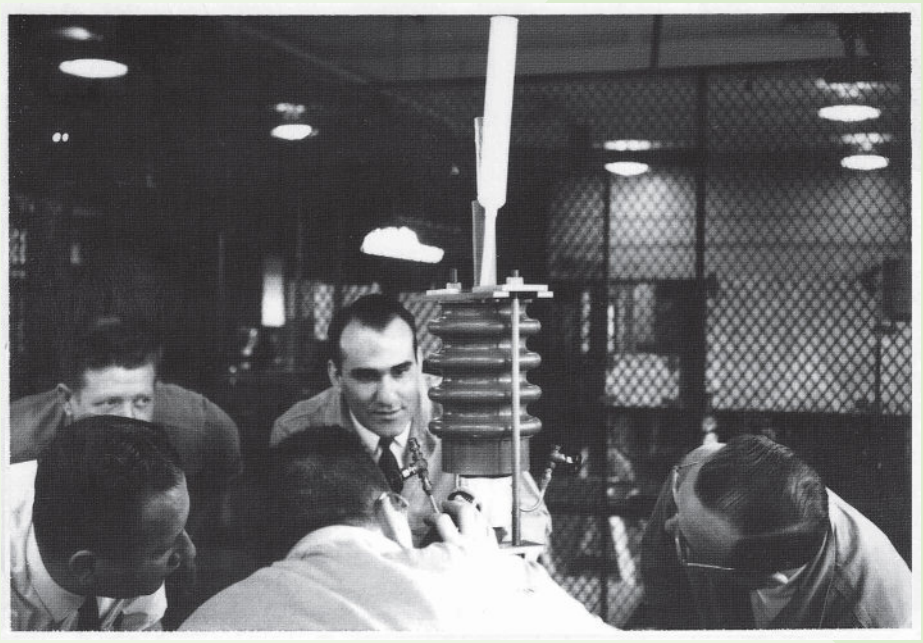
Photo: IMCORP



At Detroit Edison's research lab, he had the opportunity to experiment with different types of tests and assess their benefits and limitations. In 1963, the research team tested a sample of a newly developed extruded dielectric cable, which was insulated with polyethylene but also had carbon-impregnated fabric tape shielding over the conductor and insulation. Mashikian knew they needed to be rigorous in their testing if the new cable design was going to be successful in its application. The initial 60 Hz breakdown voltage of the newly developed cable exceeded 200 kV (conversely, the existing rubber-insulated, lead-covered cables withstood only around 35 kV). Unfortunately, after subjecting the cable sample to 3 or 4 load cycles (cyclically heating and cooling the cable to room temperature), the cable breakdown voltage dropped drastically to less than 50 kV. The team established the reason for this breakdown by testing the cable with a modified WW2 radio to detect partial discharge. They found that cyclic heating and cooling produced gaps between the conductor, the metallic shield and the insulation, causing rapid deterioration by partial discharge. Their report recommended the use of extruded semi-conducting shields. Subsequently, twelve cable manufacturers submitted samples fabricated with extruded shields. The Detroit Edison research team developed a rigorous acceptance test that included cyclic heating and cooling while the cables were immersed in water and subjected to moderately elevated voltage. As a result, only four manufacturers were qualified as suppliers to the company. By 1966, Mashikian and his colleagues wrote a report recommending improvements that led the manufacturer to develop extruded semiconducting insulation layers. Extruded semicon layers are now standard in all modern medium and high voltage cable designs.

While doing some freelance consulting, Mashikian was recruited by the University of Connecticut (UCONN), where he worked into the 1990s as a full professor of Electrical Engineering and the Director of the Electrical Insulation Research Center (EIRC) of the Institute of Materials Science. Among his accomplishments was the development of a patented technology capable of detecting defects in underground utility distribution cables. By this time, PD testing was the standard for all cable and accessory factory quality control. In 1985, when utilities funding the work at the EIRC continued to express their need to find a better way to measure cable system reliability in the field, he went to work, developing a proposal and recruiting professors with expertise in analog hardware, digital signal processing, traveling waves, and antennas. In 1989, after some initial research, Mashikian invited a top industry PD expert to review the team's progress and provide an independent review. The expert concluded, "What you are doing here is impossible," believing the background electromagnetic noise would be impossible to overcome in the field. Mashikian thanked the consultant for the review but was not deterred. By the next year, the team was performing rudimentary PD tests in the field and locating defects. Mashikian felt this innovative technology, which he and the UCONN team had developed over the course of a decade, had great commercial potential because it pinpointed the precise location of problem spots in cable systems without collateral damage, enabling companies to repair small sections of the line rather than replace the entire cable.

By 1966, Mashikian and his colleagues wrote a report recommending improvements that led the manufacturer to develop extruded semiconducting insulation layers. Extruded semicon layers are now standard in all modern medium and high voltage cable designs.



Mashikian, center, preparing a test circa 1969 at the Detroit Edison R&D lab

Photo: IMCORP

Among his accomplishments was the development of a patented technology capable of detecting defects in underground utility distribution cables.



Utility representatives witnessing prototype test on Mashikian's home driveway circa 1989



Field testing on Pikes Peak, CO with primitive equipment in 1996

In 1995, while most of his peers were looking to retire, Mashikian, aged 62, founded IMCORP with the intent to use his skills to better the industry. Between 1996 and 2000, Mashikian identified several engineers at the University of Connecticut and others from the industry to work with him and advance his vision to develop a test comparable to the standardized cable and accessory manufacturer quality control tests – an offline test utilizing a 50 or 60 Hz voltage source to produce a 30-second overvoltage and a measurement system with the ability to remove background noise in order to detect and locate PD in cable systems down to 5 picoCoulombs (pC) (standardized test parameters in Table 1).

Table 1. Standardized PD Test Specifications

Cable Component Standard	Thresholds (50/60 Hz only)
IEEE 48 Terminations	No PD >5 pC up to 1.5 Uo
IEEE 404 Joints	
IEEE 386 Separable Connectors	No PD >5 pC up to 1.3 Uo
ICEA S-97-682 / 94-649 Cable 5 kV-46 kV	No PD >5 pC up to 4 Uo
ICEA S-108-720 Cable 69 kV-500 kV	No PD >5 pC up to 2 Uo
IEC 60502 Cable & Accessories 6 kV-30 kV	No PD >10 pC up to 1.73 Uo
IEC 60840 Cable & Accessories >30 kV-150 kV	No PD >10 pC up to 1.5 Uo
IEC 62067 Cable & Accessories >150 kV-500 kV	

Uo is operating line to ground voltage, picoCoulomb (pC)
4Uo is an estimate, actually 7.9 kV/mm or 200 V/mil
IEC 60840/62067 Accessories have a 5 pC requirement

In 1996, Mashikian and his team performed the first commercial field tests: one for Northern Indiana Public Service Company (NIPSCO) and another for Colorado Springs Utilities (CSU). The CSU tests included the aged cable feeding the station atop the 4k+ meter (14kft+) Pikes Peak, finding the costly cable system was in good condition and did not need replacement. The tests at NIPSCO demonstrated the technology could easily find defective splices and even narrowed the selection of defective components to the worst three. The utility called Mashikian within a few weeks and said one of the three worst performing splices failed and they wanted additional testing services. Through 1997 and 1998, Mashikian and his team performed tests at Xcel Energy in Denver, Florida Power and Light (FPL) in Florida, and what is now Hydro One in Canada.

In 1995, while most of his peers were looking to retire, Mashikian, aged 62, founded IMCORP with the intent to use his skills to better the industry.



In 2000, FPL and Mashikian's team developed a pilot to assess 46,000 meters (150,000 feet) of buried cable systems and track the performance over the course of eight years. During those eight years, the team repeatedly tested cable systems, measured specific defect location degradation rates, and extracted samples to research failure mechanisms. The results revealed previously misunderstood delay mechanisms in cable system defect degradation and proved the predictive power of using standardized partial discharge measurements on aged cables.

During the 2000s, significant testing programs were implemented at FPL, NIPSCO, Xcel Energy and a few other utilities on hundreds of miles of cable systems with the primary purpose of assessing aged assets and optimizing repair and replacement activities. Through many challenges, technology steadily improved and, by the mid 2000s, over 95% of field assessments were achieving factory-level sensitivity (see standards table).

In the early 2000s, We Energies asked Mashikian's team to demonstrate their field diagnostic technology and compared it to the other technologies available. The technology proved to be the most reliable and was quickly adopted to commission all new feeder cable systems for We Energies. During this time, We Energies' feedback to accessory manufacturers helped improve product performance and for the first time, field PD testing was helping industry advance product technology with a level of precision never seen before.

Mashikian, who is now in his 80s, has continued to push his R&D team to advance the technology to develop additional patents in the last few years.

Photo: IMCORP

In the mid-2000s, FPL was struggling with what was thought at the time to be the largest wind farm in the world. A 300 MW wind site in Washington state was having numerous cable system failures costing on average $100,000 per outage due to lost revenues. FPL remembered the success achieved when applying PD testing to their aged cable systems and asked IMCORP if they had the capability to test new cables at wind sites. As part of a larger investigative team, IMCORP helped identify multiple issues, including overheating splices, cable manufacturing defects, termination and splice workmanship issues, and installation damage. From that experience, many engineers and technicians learned the power of using partial discharge testing to commission and identify workmanship and application problems. In fact, partial discharge testing has been so successful in eliminating significant revenue loss due to cable failure that more than 60% of wind and solar projects in North America currently specify standardized PD testing (Table 1).

By the late 2000s, several utilities were interested in using partial discharge testing to optimize repair and replacement programs, but one significant challenge still existed: the stock price of investor-owned utilities in North America is penalized when the utilities spend additional money on operating and maintenance tasks. However, in 2009, the Federal Energy Regulatory Commission (FERC) ruled the cable assessment cost may be capitalized because it enables utilities to achieve like-new performance and extend the useful life of aged cables. Within a few years, utilities like Duke Energy, Southern California Edison and Centerpoint developed large scale testing programs testing tens of thousands of cable systems, each achieving dramatic reliability improvements at significantly lower costs. Even with these achievements, Mashikian did not stop innovating. Mashikian, who is now in his 80s, has continued to push his R&D team to advance the technology to develop additional patents in the last few years. Some of these advancements include automated analysis with AI and machine learning techniques and scaling the technology to fit in small vans with Lithium-ion battery power and super lightweight air-core transformer technology.



Mashikian and university team 1996
Early IMCORP Days

There are numerous opportunities for the men and women of this generation to take what the Mashikians of the world have given us and make a positive impact on humanity. How are you going to use your expertise to leave your mark?

Today, the technology has been applied to 300 million feet of cable systems rated 5 to 500 kV in over 17 countries and 49 of the United States. Over the past two decades, utilities have used standardized PD testing services to save hundreds of millions of dollars by deferring asset replacement. Similarly, critical power and industrial facilities have saved hundreds of millions in avoided outages by commissioning their cable systems and eliminating installation errors with a standardized PD test (offline 50/60 Hz PD test with 5 pC sensitivity). In addition to the direct testing benefit, the industry has benefited from the knowledge derived from what is most likely the largest database of PD tested cable systems and service performance in the world. The database, coupled with over 8,000 defect dissections, has created a knowledgebase that has helped advance the development of cable system components with many of the large manufacturers and has initiated numerous best practices for testing and operations that can easily double the useful life of cable systems.

Stories about trailblazers who change an industry and make significant contributions to technology to better humanity are seldom simple. Mashikian's story is no exception. Mashikian's diverse life experience, unquenchable curiosity and passion for research and technical excellence, and ultimately the drive to make the world a better place, has paved the way for the next generation. In the second age of electrification, it is an exciting time to be in the electric power industry. There are numerous opportunities for the men and women of this generation to take what the Mashikians of the world have given us and make a positive impact on humanity. How are you going to use your expertise to leave your mark?

Steven Watt

Senior Product Marketing Manager
at Sentient Energy

Interview with **Steven Watt**

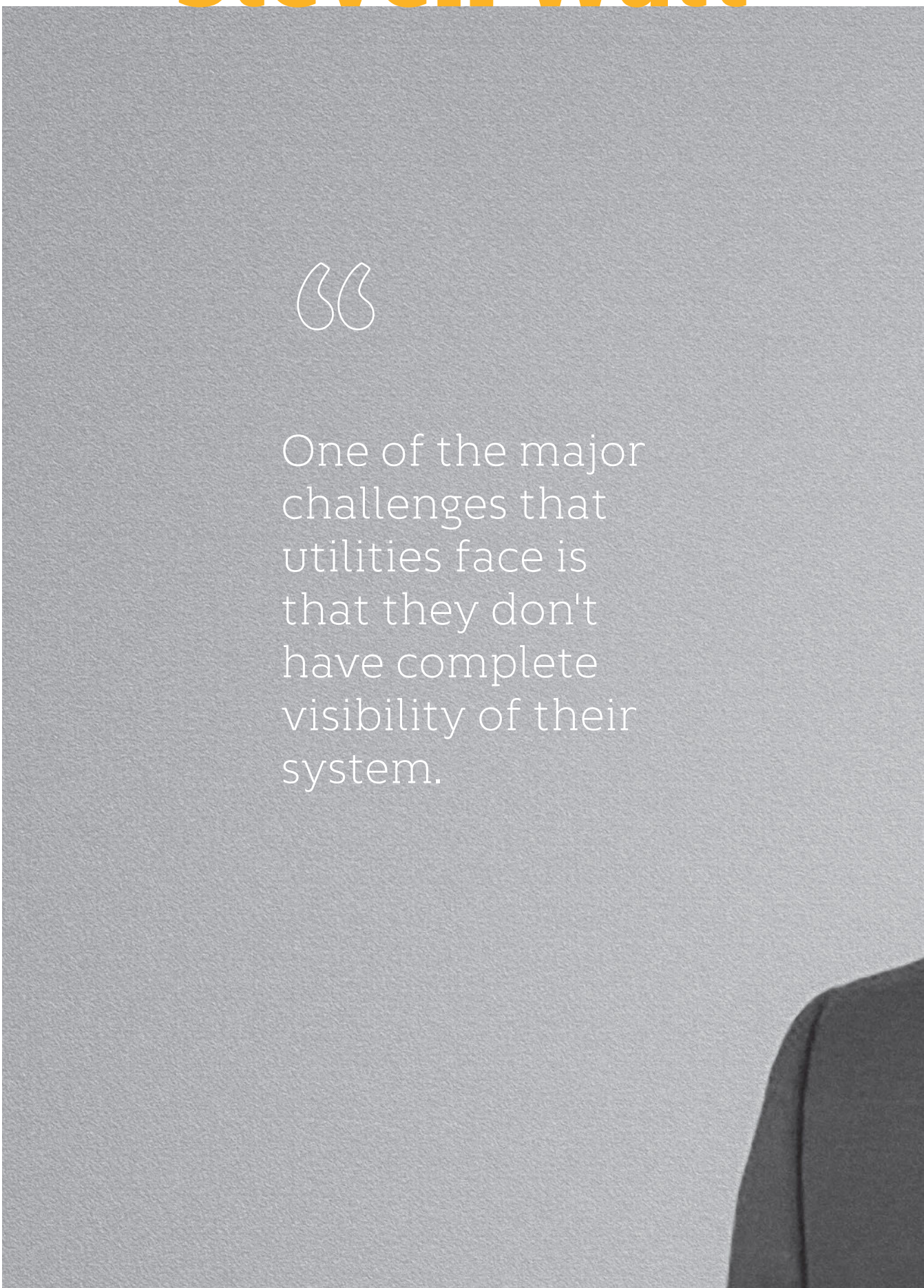




Photo: Sentient Energy

Steven Watt is the Senior Product Marketing Manager at Sentient Energy, a company that provides innovative line sensing, data analytics, optimization and control technologies for the distribution grid. In this interview Steven talks about problems that the utility industry is currently facing and how his company helps solve them.

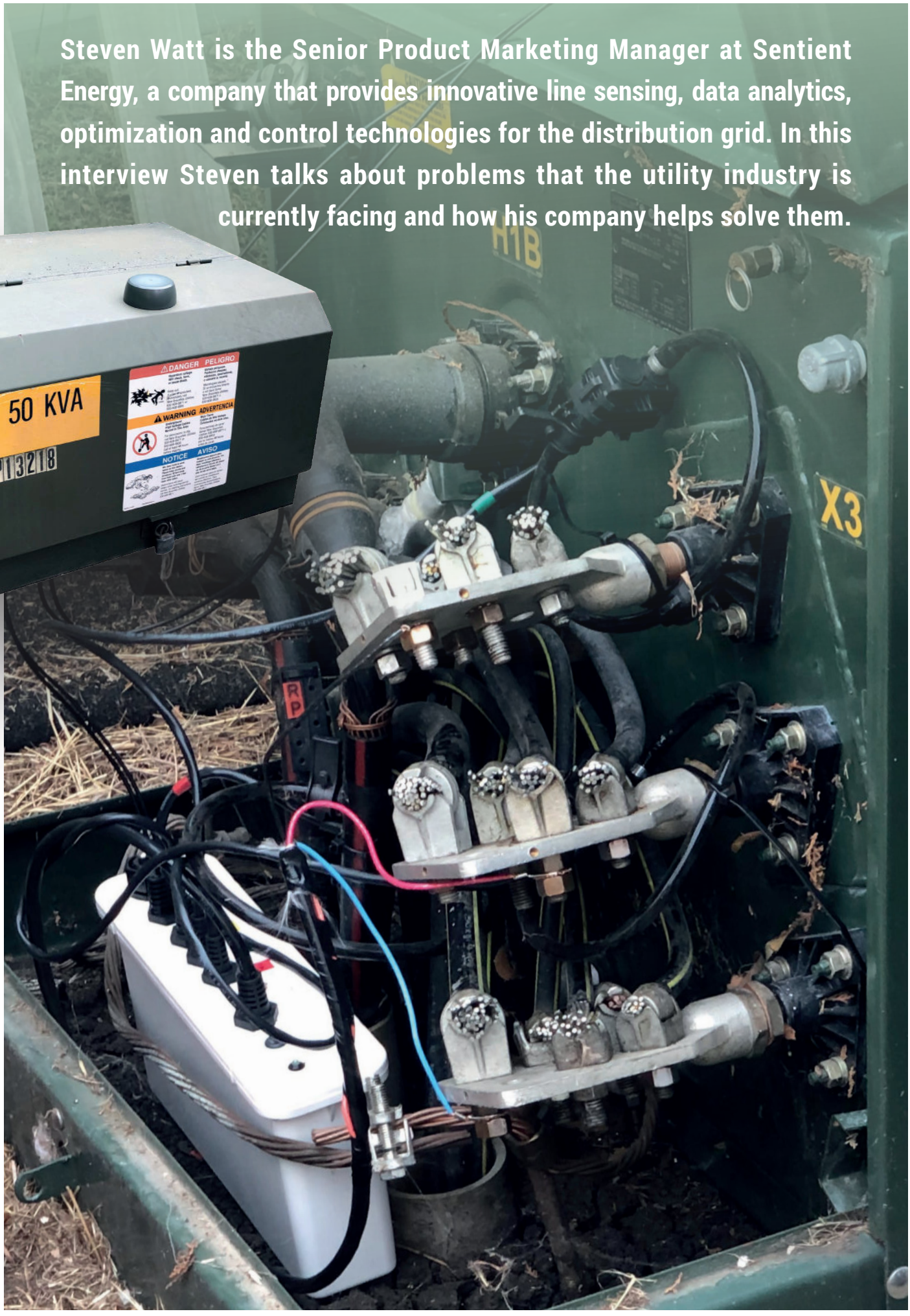


Photo: Sentient Energy

Alan Ross: Steven, welcome to this interview.

One of the things that we at Power Systems Technology are trying to do is to find out the challenges and problems that the energy market is facing, and then to hear from Thought Leaders on how these challenges are being met. You are in the electric utility industry. Could you tell me just a little bit about your background? How long have you been in the industry?

Steven Watt: Thank you, Alan. I worked for over 20 years in the IT industry, and I was working quite a bit on energy efficiency in IT products. Then I jumped to the power utilities market in 2012 where I have been for the last ten years, focusing on networking and communications for utilities.

AR This is interesting. You jumped in just when a lot of the problems really got exacerbated. Because it's no longer just about the power, it's also about the data and it's about the IT. Your company solves problems. Sentient Energy offers intelligent line monitoring solutions both underground and overhead, but what do you think utilities are really facing in terms of problems with their lines today?

SW I think one of the basic things is that they don't have complete visibility of their system. They can often see down to the distribution substation if they have communications into that area, but then they don't have much visibility beyond it. Utilities are also facing challenges on feeders and laterals with reliability problems, which are hard to solve if you can't see what's going on in those parts of the system.

AR When you say "see", you are not talking about it in a visual sense of the word. And while the visual is also important, you are actually talking about seeing the condition, seeing what is going on, seeing the faults, correct?

SW That's right. Mainly what I am talking about is monitoring current so you can detect and locate faults, but also monitor load so you can see when load is at levels that are too high, etc. But then beyond that, what utilities told us they want to do is also monitor some assets. And I think this has become a lot more critical because of the long supply chain lead times on assets like transformers. I would say they want more visibility. They want to locate faults more precisely so they can send crews directly to the faulted segment with the right equipment, the right trucks, etc. They want to monitor their critical assets proactively instead of using a run-to-failure model.
And this is especially important when you think about how a lot of people are working from home and there are more requirements now to have high reliability on laterals and underground residential distribution because people are counting on the power more than they used to.

Utilities want more visibility and to be able to locate faults more precisely so they can send crews directly to the faulted segment with the right equipment. They want to monitor their critical assets proactively instead of using a run-to-failure model.

AR One of the big new problems is also the fact that we are moving from a step-down system, where you generate power and then step it down, to what I call a "step everywhere" system, where EV charging is taking power, giving power, there are renewable sources, etc. So, all of the assets you are talking about are being stressed as they've never been before. I like the idea about improving visibility or monitoring from the distribution down into the customer's markets because visibility of that is still lacking. The utilities thought of putting all these wonderful monitors on houses to let them know how much to charge people, but they still don't have the visibility of the line, do they?

SW They have better visibility now at the meter and usually, like we said, at the substation. The space in between - we call that the grid edge, is the space that we have been focusing on lately. A lot of people include the meter in the grid edge, but we consider it to range from the substation down to the meter. And that's where there is generally poor visibility and big opportunities for improvement.

AR Speaking of grid edge, I happen to be on the steering committee of the IEEE Grid Edge Conference and Exposition in San Diego in April 2023. IEEE has a PES T&D conference every two years and in between those we are going to organize IEEE Grid Edge conference. I would love to have you there.

You just said you are in the IT world, so you understand data. I feel like there is more data going somewhere and fewer people looking at it and making decisions with it and about it. So, could you talk a little bit about that? When you talk about monitoring, that to me means you are looking at data. How do you at Sentient Energy handle that?

SW First of all, when we talk to our customers, we always try to start with pinpointing exactly what problem needs to be solved. Are we trying to reduce outage duration?

Okay, that's one set of data. Are we trying to improve phase balancing? That's another. And asset monitoring is yet another. But I believe the key to data is having the ability for the customer to select the data they want, and how frequently they want to receive it. This is basic. Then also to have support for multiple deployment models of the software. A lot of utilities consider this OT data, and they want it to be on premise. But as you start to look at opportunities like predicting outages or trying to apply analytics to data to predict and be proactive, then deployment models such as the Cloud offer a lot of advantages. So, what we are trying to do is offer multiple deployment models, have an on-premise model, have a Cloud, and then have a hybrid, too, where you can mix the pieces, and that in turn helps clients in the long term to manage their data more efficiently.

What we are trying to do is offer multiple deployment models, have an on-premise model, have a Cloud, and then have a hybrid, too, where you can mix the pieces, and that helps clients manage their data more efficiently.

AR Data is one thing. Data turned into information is another. Information turned into wisdom is what customers really need. They need the people in the marketplace to bring ideas and solutions to them that provide not data in its raw form but what that data tells us.

Obviously, you have a lot of data that is not just about one customer, it's about all customers. And you can put that data together in a better form than one customer. Is that correct?

SW I think that's the advantage when we get into analytics. We have an analytics team that is looking at data from multiple customers, and we only really focus on one industry - power utilities. A lot of the analytics companies do analytics on ten different markets: manufacturing, healthcare, and so on. We, on the other hand, deep dive into power utilities. And we feel like that gives us a real advantage because when you are looking at waveforms for the power system and you get to know the power system, you can disregard a lot of "background noise" like a capacitor firing here, or maybe some switching going on there if you have that deeper knowledge. I think part of it is also that in order to really make good use of the data, you need to have some depth of knowledge on how the power system works.

AR Steven, you have a new solution. And we try not to be product-specific here, but I love what Sentient Energy is doing. The idea that there is a part of the grid between the meter and the distribution center that is forgotten is incredible. Tell me more about what kind of solutions you have come up with more recently.

SW We started with intelligent line sensors for overhead, and we did the feeders first - that's our MM3 product. Then we did the laterals and moved to underground and did the feeders. The product we just released is generally for the single-phase laterals or so-called underground residential distribution. The overhead sensors actually hang on the line and they are not installed inside anything. The underground feeder product is typically installed in switch cabinets. But it could also be installed in underground vaults. Now, when we built this one for the underground residential distribution, the logical place to put this product is in the transformer cabinet. What's exciting about this product - called the UM1, is that we see this as the intersection of line sensing and transformer monitoring. Because when we built this line sensor, we didn't just do our normal line sensing features on the primary side. We also decided to monitor the secondary side of the transformer and provide some transformer monitoring capabilities. And so far, we have done pilots with this product with about half a dozen customers that have tried it, the thing that the customers are most excited about is the transformer monitoring.

What gives us a real advantage is that we only focus on one industry - power utilities. Having the depth of knowledge on how the power system works helps us make good use of the data.

AR I know what you mean. I'm a transformer guy, so when you said what you said, I thought, "Forget the rest of this, tell me about the transformer side of this thing."

SW I understand. We are coming from the line sensor side, and we are saying, "These guys are crazy about the data on the transformers!" And we have already found transformers that need to be replaced right away.

AR Steven, you just touched on something very important and that is run-to-failure. Distribution transformers, for the most part, run to failure. And this is a global phenomenon, not just in the U.S. and Canada. I don't think people realize how much more money it costs to replace a transformer that's failed than to replace it before it fails. Tell us about what you found as you went on.

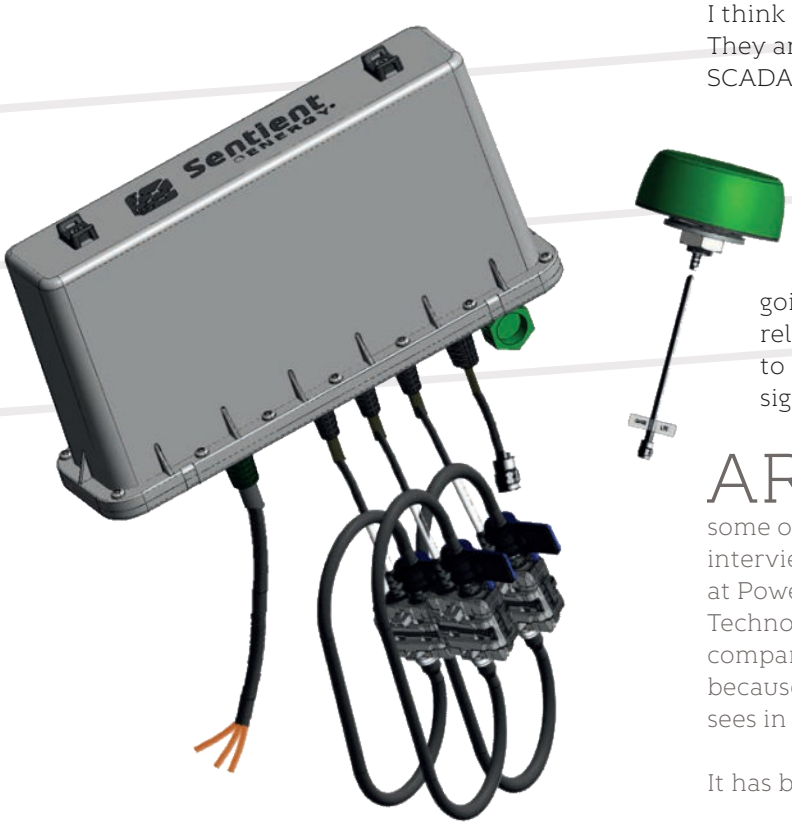
Photo: Sentient Energy

SW We discovered a couple of things. One is that utilities have been used to this idea of a duck curve for load data. And what has happened is that solar and EV have really done a number on the duck curve. It's no longer the way it used to be.

Our new product is the intersection of line sensing and transformer monitoring. Apart from line sensing features on the primary side, the sensor also provides transformer monitoring capabilities, which our customers find particularly exciting.

AR Yes, it's now called the three-humped-camel curve.

SW Yes. And I think it is interesting to see it and see what's really happening. The other thing is that on this product where we monitor the transformer, we can also monitor reactive power and kVARs. So, in some cases, what we have seen is that the solar is actually too high in voltage, and it's basically creating negative kVARs. And some of the EV chargers, especially the ones that aren't as expensive and are not using batteries, tend to create voltage sag. They tend to be inductive. What you have is this capacitive load coming from the solar system and some increased inductive load.



These intersect at the transformer, creating stress on the transformer because those two load waveforms don't match up.

The grid edge is the space in the network ranging from the substation down to the meter. This is where there is generally poor visibility and big opportunities for improvement.

AR Before we close this interview, give me just one thought. What do you see as the future? What are the future problems and future solutions within the utility industry in North America?

SW From our perspective, and we are focused on the segment between the substation and the meter, I think the future opportunity is to increase the visibility of this segment and be able to react more effectively to problems that occur there and reduce outage durations. That's the work that a lot of utilities are doing today. But what our solution does is it helps you immediately. It allows you to get a return on investment today because you are reducing your CMI. It also creates a platform where you can start building toward the predictive capability, because it doesn't happen immediately. You have to capture a lot of data, and it can take months or years to really build enough data where you know what normal is and then you can start to look for anomalies. I think the other big thing is using anomalies. They are not going to be shown or visible in SCADA because they are not creating interruptions. But using anomalies to predict events like equipment failure and vegetation issues, I think those are things that are going to happen. We are just in the early stages of it, but I believe they are going to happen and they will both improve reliability. Because having the ability to predict and eliminate an outage is a significant reliability improvement.

AR Steven, thank you for joining me on this interview and I would like to get some of your other geek-type experts for an interview because one of the things that we do at Power System Technology and Transformer Technology is getting people like you and companies like yours to share your knowledge because you see more than one utility engineer sees in his career.

It has been great talking to you.

SW Thank you for inviting me. It's been great!

Operational Technology (OT) Security in Substations

by **Bryan J. Gwyn**
and **Sagar S. Singam**



Operational Technology (OT) is a broad category of programmable systems or devices that interface with or manage equipment that interacts with the physical environment [1]. Organizations have tended to deploy specialized point solutions to solve specific challenges, as digital innovation has spread IT and OT networks have fused. These approaches to OT security resulted in a complex network in which the solutions could not communicate information and give complete visibility. Network OT typically reports to the COO, and IT to the CIO, resulting in two network security teams, each covering half of the network. There are several ways to manage OT security, and this article focuses on asset management and the need to patch those assets using a typical architecture.

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Bryan J. Gwyn is Doble's Senior Director of Solutions at Doble, with over 30 years of international experience in electric utility Transmission and Distribution protection, control and telecommunication engineering, operations and management. Leading a team of global subject matter experts, he is responsible for the development of Protection, Asset Management, Monitoring and Security solutions. Bryan received his BEng (Hons) Electrical and Electronic Engineering degree and his PhD at City University, London, UK. He is a Chartered Engineer and Senior Member of IEEE.



Sagar S. Singam is a Senior Cybersecurity Engineer at Doble with over 8 years of experience in industrial and IT cybersecurity architecture. He obtained his Master's in Information Assurance and Cybersecurity from Regis University. He is a member of IEEE PES.

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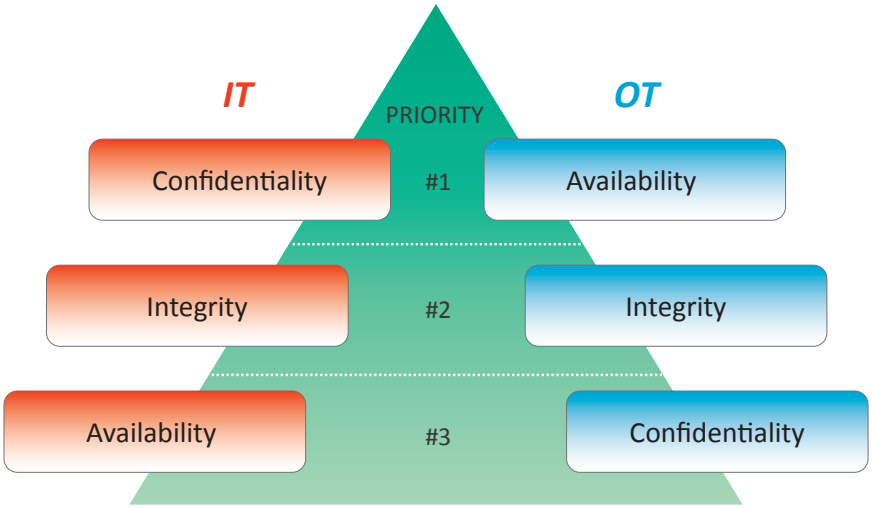


Figure 1. CIA Triad

Confidentiality-Integrity-Availability (CIA) Triad

The CIA Triad is a data security concept. It directs a company's data security efforts. In fact, including these ideas in any security program is ideal. The three pillars of security architecture are as follows.

Confidentiality

In today's world, it is critical for people to protect their sensitive private information from unauthorized access. Protecting confidentiality necessitates the ability to define and enforce specific levels of access to information. In some cases, this entails categorizing information into different collections based on who needs access to the information and how sensitive the data is—the amount of damage suffered if confidentiality is breached. Access control lists, volume and file encryption, and Unix file permissions are some of the most used methods for managing confidentiality.

Integrity

The "I" in the CIA triad represents data integrity. This critical component of the CIA Triad is intended to prevent data from being deleted or modified by unauthorized parties. For example, online buyers demand accurate product and pricing information and assurances that the quantity, cost, availability, and other information will not change after they make their order. Data integrity safeguards include encryption, hashing, digital signatures, and digital certificates.

> Confidentiality, Integrity and Availability make the CIA Triad, and they are the three pillars of security architecture.

Availability

The availability of your data is the focus of this stage—the third in the CIA Triad. High availability systems are computing resources with architectures specifically designed to increase availability. The most well-known attack that jeopardizes availability is called a "denial-of-service" attack, in which a system, website, or web-based application has its performance purposely and maliciously compromised, or the system is rendered inaccessible. The breakdown of hardware or software, power outages, natural catastrophes, and human error are other possible risks to availability. The information must be protected and made available when needed, which requires that authentication procedures, access routes, and systems all function effectively.

The CIA Triad is all about information and data security. But the first thing to note in Figure 1 is that, in general, IT and OT risk management priorities differ. **IT prioritizes confidentiality, while OT prioritizes availability, followed by integrity and confidentiality (A-I-C).**

IT and OT Security Management in Substations

Attacks on critical infrastructure have caused power outages and compromised sensitive data, as well as evoking nightmare scenarios involving environments such as water supply systems, petrochemical installations, nuclear power plants, and transportation infrastructure systems, all of which rely on operational technology (OT) and, to varying degrees, information technology (IT) [2]. The primary focus of IT is data and its free and secure flow. It is fluid and has many moving parts and gateways, which makes it more vulnerable and provides a larger surface for a broader range of constantly evolving attacks. Defending against attacks entails protecting every layer and constantly identifying and correcting flaws to keep data flowing.

> While IT prioritizes confidentiality, OT prioritizes availability, followed by integrity and confidentiality (A-I-C).

Traditionally, IT and OT had distinct roles. OT teams were accustomed to working with closed systems that relied heavily on physical security mechanisms to ensure integrity. The industrial Internet of Things (IIoT) and the integration of physical machines with networked sensors and software are blurring the lines between the two. As the Internet of Things (IoT) connects, communicates, and interacts with more objects, the number of endpoints and potential ways for cybercriminals to gain access to networks and infrastructure systems grows. Interaction between operational

and information technology systems is essential for the Digital Substation. Control systems, SCADA, and industrial networks connect to IT components like processors, storage, and systems management. **Data collected by physical and Industrial Internet of Things (IIOT) devices can be used to identify problems and improve efficiency with IT-OT integration.**

Understanding the difference between IT and OT is crucial because the two are frequently confused. While operational technology controls equipment, information technology (IT) controls data. IT mainly ensures systems and data confidentiality, integrity, and availability.

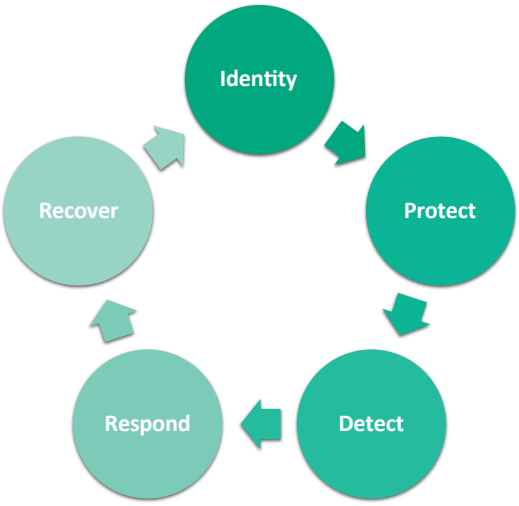


Figure 2. NIST Cybersecurity Framework (CSF)

> Data collected by physical and Industrial Internet of Things (IIOT) devices can be used to identify problems and improve efficiency with IT-OT integration.

OT Security Governance

The Federal government has issued many executive orders in the past to strengthen the cybersecurity posture of vital infrastructure [3]. President Biden most recently signed Executive Order 14028 "Improving the Nation's Cybersecurity" in May 2021 to protect critical infrastructure [4]. This directive focuses on modernizing cybersecurity requirements such as data encryption at rest and in transit, a zero-trust architecture, and the deployment of multifactor authentication and data encryption within a certain time frame. This demonstrates that even today, having a basic security foundation, such as the NIST Cybersecurity Framework (CSF), which went into force nearly a decade ago, is vital for critical infrastructure organizations. The NIST CSF consists of the framework core, profiles, and implementation tiers. While the core functions of the NIST CSF include categories, subcategories, and informative references, **we will focus on the first two core components shown in Figure 2 of this framework from a 1000-foot perspective.**

Asset Management, a comprehensive inventory of all OT assets, is one of the essential core components of an OT asset database. Not only hardware but also a comprehensive view of the data, personnel, devices, systems, and facilities that enable the organization to meet its objectives. They must be identified, and their importance in business objectives and risk management must be clearly established.

Database management software can bridge the divide between competing IT and OT priorities. Look for a relational database architecture that will support a central data warehouse structured for universal interfacing to external systems. Bringing such a system online will integrate OT data into a hub where asset management and work management will intersect.

Connecting dataflows emanating from different sources enables OT teams to have the data integrity, availability and confidentiality they prioritize while critical elements related to human performance and network security remain intact for IT intents and purposes. The ideal OT database management system will accept user authentications developed in the IT domain which complements the corporate cyber security measures put in place for user (and device) password management, which assures data security and integrity as well.

> The ideal OT database management system will accept user authentications developed in the IT domain which complements the corporate cyber security measures put in place for user (and device) password management, which assures data security and integrity as well.

After identifying and categorizing your assets, you should take proactive measures to safeguard them from internal and external cyber threats. Security maintenance rules and practices, including **software patch management** and whitelisting, must be created and implemented for the NIST CSF's Protect component.



Figure 3. Integrated OT and Security Management Platform

These two methods are most often used in vulnerability management and protection.

In practice, maintaining approved software is a labor-intensive obligation with tremendous implications on IT resources. For instance, some electrical equipment requires software that could be many years older than software used with newer equipment. Monitoring the wide variety of software applications used in OT, not to mention the sheer quantity of laptop computers and electrical device firmware versions, is a major effort that directly impacts IT teams. Regardless, it is critical that the software and computers used in OT do not pose any cyber security vulnerabilities that could risk cyberattacks successfully entering critical infrastructures.

Regulatory standards, like NERC CIP-10 for example, spell out baseline requirements IT must abide by in regard to cyber security that affects OT. According to NERC, any computerized device that is connected temporarily to any component of a cyber system is classified as a Transient Cyber Asset (TCA) and must not only be hardened, but also receive software and security patch updates regularly. Failure to provide evidence that NERC requires during audits can incur financial penalties.

Facing heavy responsibilities and internal costs, IT can look to a managed program from a vendor that can augment in-house resources with proactive software and security patch monitoring. Look for a program that offers a comprehensive and secure portal that both centralizes management functions and automates approving and deploying patches and updates to TCAs.

> The CIA Triad, like the NIST CSF or any other successful security practices like asset management and software patch management cycle, ensures resistance against attackers.

The solution should accommodate all whitelisted software regardless of the operating systems older applications might require, and it should offer tracking and reporting tools that promote NERC compliance audit readiness. Additionally, the solution should scale to your requirements and offer flexible commercial terms.

Summary

Finally, because every business has various security concerns, the CIA Triad and NIST CSF are not a one-size-fits-all solution for handling OT Security challenges in Substation environments. This is where a solid security foundation comes into play, allowing organizations to assess which solutions are necessary to safeguard their vital infrastructure. Many high-profile cyberattacks on industrial companies in recent times have influenced how corporations approach security. The CIA Triad, like the NIST CSF or any other successful security practices like asset management and software patch management cycle, ensures resistance against attackers.

To sustainably contribute value to and seize the benefits of the future digital economy, every company must withstand cyber disruption.

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SMP Robotics presents a new innovative solution in the field of automated thermography and infrared inspection.

These are the next generation of inspection robots series S3.2 that is equipped with a dual PTZ camera consisting of a thermal measuring camera and a high-resolution optical range camera.

The S3.2 robots can automatically move along a pre-programmed route, stop near electrical and other equipment subject to thermography, and aim a PTZ camera on it. Next, the manual remote control mode of the PTZ camera is turned on. The remote operator can inspect equipment by examining two video images, visible and infrared spectrum.

Upon completion of the inspection carried out under the operator's control, the robot will continue its automatic movement to the next piece of equipment. The 2022 model provides for installing three types of PTZ cameras from different manufacturers. This helps to avoid the export restrictions of several countries. Also, the list of additional equipment installed on the robot has been expanded. The multi-gas detector is available with the request and installation of a highly sensitive microphone, an ultraviolet camera, and weather sensors.

The robot is equipped with a metal fence detector as standard to operate on the territory of electrical substations. The robot has a body made of Fiberglass and has a coating that protects against strong electromagnetic fields, this allows you to use it close to high-voltage equipment and electrical lines. The robot is on standby with charged batteries for most of the day. This allows you to quickly start using it in an emergency with a complete blackout of electrical equipment. Due to its autonomy, the robot can transmit images from onboard cameras for a long time. Make automatic patrol through the territory for its detailed inspection with a PTZ camera if necessary.

THE DESIGN OF THE SECURITY ROBOT ENSURES ITS RELIABLE MOVEMENT ON AN UNEVEN SURFACE COVERED WITH RUBBLE OR STONES. THE INSPECTION ROBOT IS DESIGNED TO WORK IN AN OPEN AREA AND HAS AN EXTENDED RANGE OF OPERATING TEMPERATURES.

SMP S3.2
Key features of Outdoor Electrical Inspection robots

- Automatic unmanned inspection of unattended facilities
- Data downloading capability
- API integration (TBD)* approval required by SMP
- Temperature identification
- Remote camera control
- Autonomous movement on pre-programmed patrol routes
- Multi-robot (group) patrolling of the security area or single robot patrol
- Transmission of ONVIF videos and alarm events over 4G or WiFi
- Temperature ranges > -20°C – +55°C
- Automatic travel between pre-set inspection positions
- Tele-operation control mode for thermography inspection
- Autonomous movement by pre-programmed route for observation
- 360-degree video surveillance and human detection by six HD cameras
- Transmission of ONVIF video and alarm events over 4G or Wi-Fi
- Sound notification, IP intercom, alarm button
- Automatic charging station for 24/7 autonomous operation
- Options: microphone, multi-gas detectors, UV camera

Photo: SMP Robotics Systems





Electrical equipment inspection and video observation

They enable all models of robots manufactured by SMP Robotics continuously. The new model, S 3.2, can avoid obstacles automatically, stop when there is a significant deviation from the inspection route, and return to charging when the batteries are discharged. The inspection robot is charged automatically using the charging station included in the delivery package. The design of the security robot ensures its reliable movement on an uneven surface covered with rubble or stones. The inspection robot is designed to work in an open area and has an extended range of operating temperatures. To protect the robot against direct sunlight in hot climates, a shelter with an automatic charging station is offered for delivery. It has six circular video surveillance cameras to monitor the robot's work and conduct security patrols.

The cameras have high resolution and allow you to inspect the territory along the path of the inspection route. The image from these cameras is analyzed by a separate onboard computer of a panoramic video surveillance system for detecting people. If they are detected, two-way voice communication can be established by using the intercom integrated into the robot. Video transmission from the robot, information about its location, and operation of systems are carried out via 4G or Wi-Fi wireless channels. The status and location of robots on inspection routes are displayed in the web-based service for group monitoring of the operation of robots. Video from all robots cameras is stored on two removable HDDs. This allows you to keep records of inspections made by the robot for several weeks. Remove HDD for later copying without using wireless channels.

THE DEPLOYMENT OF AUTONOMOUS AI-POWERED ROBOTS CAN SIGNIFICANTLY REDUCE THE OPERATIONAL COST OF DOING BUSINESS, IMPROVE THE QUALITY OF THE MONITORING AND MAINTENANCE OF COSTLY EQUIPMENT, AND REDUCE BUSINESS LIABILITIES AND INSURANCE PAYOUTS.



Deep Learning in Infrared Non-Destructive Testing

The security robot features a dual-spectrum PTZ camera with heat and visible radiation sensors.

Using photo and video materials obtained directly from the serviced facility will allow you to fine-tune diagnostic algorithms and detect signs of abnormal equipment operation at the earliest stages. Equipping the inspection robot with an additional microphone and UV camera will allow you to combine information from different types of sensors. Deep Learning in Infrared Non-Destructive Testing This approach allows us to identify complex patterns of the appearance of signs of equipment malfunction and localize them. Regular inspection of electrical equipment during the day allows you to collect information about operating modes at different degrees of load, which is especially.

The following model is already successfully operating in several countries worldwide, including North America, countries of the Persian Gulf, and Europe.

The deployment of these autonomous AI-powered robots can significantly reduce the operational cost of doing business, improve the quality of the monitoring and maintenance of costly equipment, and reduce business liabilities and insurance payouts.

Photo: SMP Robotics Systems

A BETTER ENERGY FUTURE IS A FUTURE OF COLLABORATION

Inspire. Empower. Advocate.



WPS Women in Power Systems

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Efra F. Usmani



Efra F. Usmani is a Team Lead and Project Manager of the E-Mobility Department at Power Technology Research (PTR). As a nature lover and a traveler, she likes to see the role she plays as part of the energy transition that helps preserve the planet.

From childhood, Efra loved Mathematics and Physics. This interest led her to opt for studies of Electrical Engineering at the Lahore University of Management Sciences (LUMS) in Lahore, Punjab, Pakistan. During her studies, Efra found her interest in the power and renewable energy sector and would later do her senior year project on the topic of renewable energy. **She served as Vice-President of the IEEE LUMS Chapter in her junior year and as President of the IEEE Power and Energy Society (PES) in her senior year.** She was also involved in initiating the first Social Responsibility Program (SRP) of her society along with her twin sister who was working as the President of IEEE Women in Engineering (WiE) LUMS. **During her undergraduate years she did internships at the National Transmission and Dispatch Company of Pakistan (NTDC) as well as in the switchgear component manufacturer company Pak Elektron Limited (PEL) and at Telecommunications Company ZONG.** She graduated from LUMS in 2019, earning an Electrical Engineering degree with a focus on power and renewable energy. **Efra started her professional career as the lead EV charging infrastructure Analyst for the Western and Eastern European markets and in the Power Grid department at PTR.** During her time there she worked with some of the biggest Transmission and Distribution (T&D) and E-Mobility clients and was part of projects and research on a global level. **At her current position as Team Lead and Project Manager of the E-Mobility Department at Power Technology Research (PTR), she keeps up to date with the latest trends in the industry and enjoys working in this high-impact field of the energy sector.** Efra is a big traveler at heart and loves the mountains and rivers of the beautiful Northern areas of Pakistan. **She spends her weekends going out and spending time with her family, reading books and watching informative documentaries.**

Source: **Efra F. Usmani**

Photo: Efra F. Usmani, rawpixel.com

PTTX actively adheres to the Carbon Neutrality Initiative and endeavors to improve its transformer core manufacturing technology

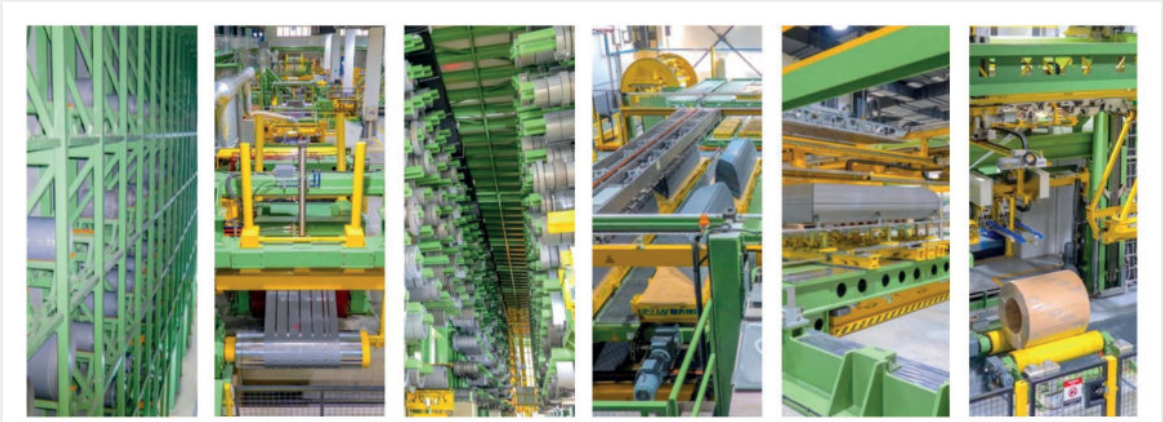


With climate change having become a common issue for the mankind, carbon emission has become the focus of attention around the world. In 2020, China set the goal of "Carbon Peak by 2030 and Carbon Neutral by 2060".

Photo: PTTX

With climate change having become a common issue for the mankind, carbon emission has become the focus of attention around the world. In 2020, China set the goal of "Carbon Peak by 2030 and Carbon Neutral by 2060".

PTTX has been actively adhering to Carbon Neutrality and assuming Carbon Responsibility. PTTX has been taking the lead in low-carbon emission and carbon reduction intelligent manufacturing from various perspectives, such as harmless raw material, clean production, reclamation of wastes, low carbon energy source, and other aspects. PTTX is credited as the "Green Factory of Jiangsu Province" and "Wuxi Smart Factory" by the Chinese government.



PTTX – Innovation in multiple aspects, the pioneer of Green Smart Manufacturing

1. R&D and new patents

(1) PTTX provides the clients with Eco-design scheme of transformer cores. Through the application of the new materials of PTTX, with the structure design and new processing technology such as multi-step overlapping joints, transformer core products have achieved the low-noise-and-low-iron-loss requirement. It has been test proven that the power loss of the transformer could be reduced by 10%.

(2) In 2021, a total of 32 new patents were applied by PTTX, including 15 invention patents and 17 utility model patents.

PTTX has successively formed strategic partners with reputable scientific research institutions like Wuhan University of Science and Technology (ranking top 103 in China), Xi'an Jiaotong University (ranking top 10 in China), and large state-owned enterprises such as Beijing Shougang Co., Ltd (ranking top 5 by market share in China). The company has also built a postgraduate training base with Xi'an Jiaotong University, a joint laboratory with Beijing Shougang Co., Ltd on electrical steel application technology, and a provincial-level high-voltage special transformer core engineering technology research center. These R&D infrastructures enable PTTX to provide clients with green and low-carbon products that meet the standards of various countries.

2. Factory management system building

PTTX has met GB/T 19001 requirements and passed the GB/T 19001-2016 certification. Since June 2020, the company has established a relatively complete GB/T 23331 energy system document. In June 2021 PTTX officially completed RB/T 119-2015 energy management system certification audit.

3. Equipment operation and control

(2) PTTX has been strengthening the standardization building of the factory, such as the improvement of the standardization of vertical and horizontal shear tool, tool storage, transportation, inspection, and the standardization of table setting, assembly, horizontal shear punching die, track.

PTTX has been conducting equipment upgrading and technological innovation. It has achieved a variety of phased achievements, such as a 3% increase in the utilization rate of silicon steel materials, a 5% reduction in the process coefficient of each grade of electrical steel, and a 5% increase in energy efficiency. In particular, the research on the utilization rate of electrical steel coil, through the transformation of equipment control, will reduce the waste of materials, making contributions to carbon neutral initiatives.

4. Green production and smart manufacturing

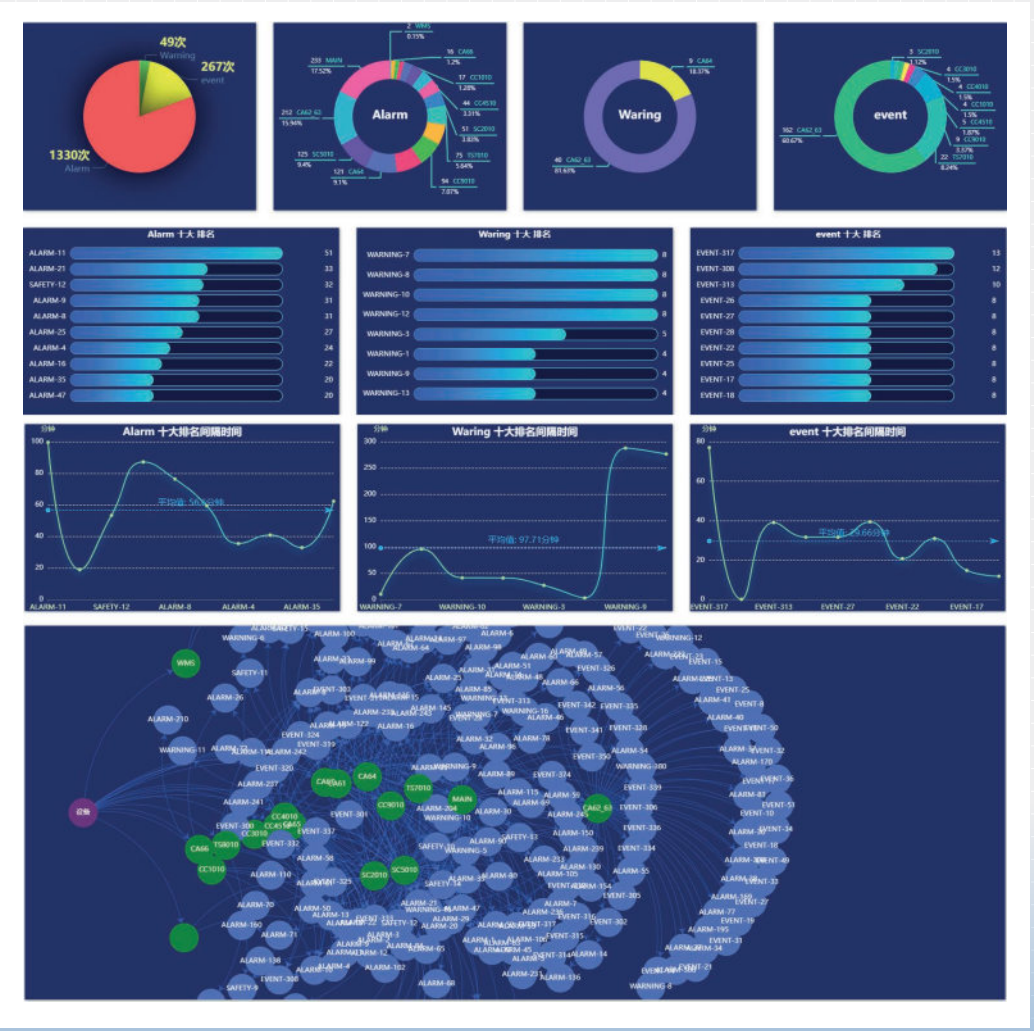
(1) PTTX pays great attention to the research of the application of environmental-friendly water-borne paint in different voltage levels of transformer core. Through independent research and the development of water-soluble paint instead of solvent-based paint, the painting operation will be safer and more environment friendly.

For product packaging, transportation, and application, PTTX applies vacuum packaging to replace the rust-proof oil coating products. This eliminates the pollution and impact on transformer performance caused by rust-proof oil.

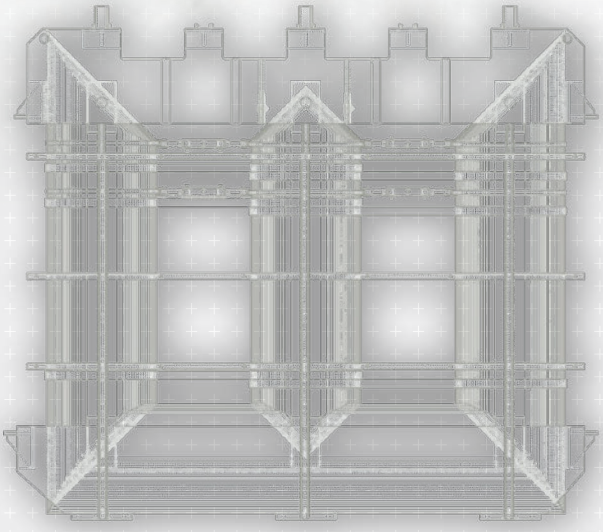
(2) PTTX adheres to smart manufacturing. By adopting advanced integrated RFID technology, and establishing enterprise resource management system, including Enterprise Resource Planning (ERP), Manufacturing Execution System (MES), Product Data Management (PDM), Supervisory Control and Data Acquisition (SCADA), Distributed Control System (DCS), Enterprise Command Center (ECC), Office Automation (OA), Advanced Planning and Scheduling (APS), Customer Relationship Management (CRM), Warehouse Management System (WMS), enterprise cloud construction, etc., it ensures an intelligent, digital, and automatic enterprise management and production.

(3) Establishment of an intelligent digital equipment model. PTTX has established a complete set of intelligent digital equipment model to realize the digital management and automation of the whole life cycle management of equipment, tools, molds, and spare parts. The system also realizes the real-time online feedback of equipment maintenance and automatic rolling scheduling of equipment maintenance. It continuously improves equipment support capacity, reduces equipment failure rate, prolongs the service life of equipment and equipment stability.

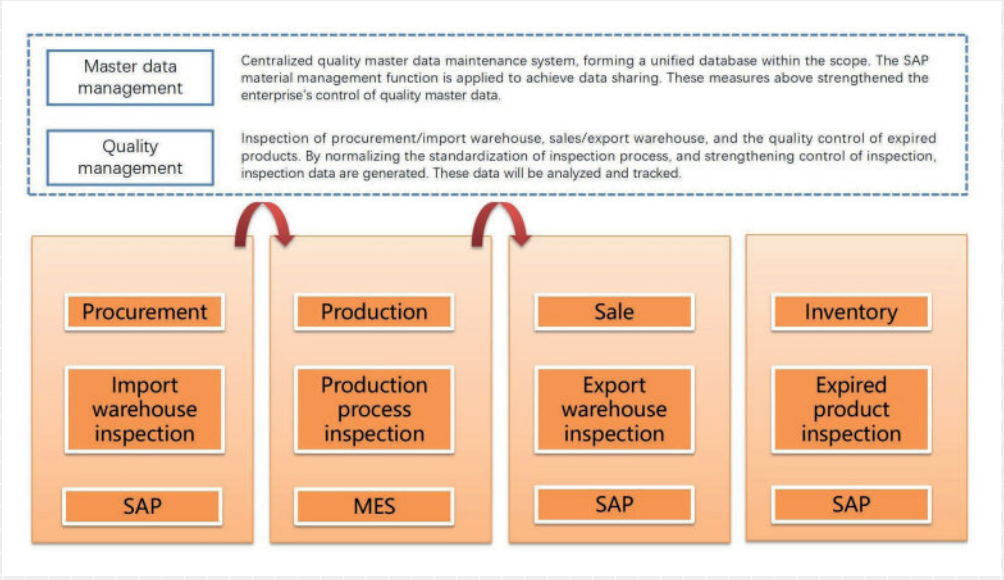
(4) PTTX has introduced an automatic docking big data platform. For each process, a quality digital model was established. By collecting the quality data of each process, the model automatically collates, summarizes, and analyzes the inspection data, monitoring product quality in real-time. The platform can find unqualified products in time and give production feedback accordingly. It reduces the production and outflow of defective products and improves the controllability and stability of the overall quality of products.



Digital model of intelligent equipment



The model of transformer core



Intelligent digital quality model

Propel a green development

(1) With the full implementation of the new version of China's "Power Transformer Energy Efficiency Limit value and Energy Efficiency Grade" (GB 20052-2020) standard, PTTX will continue to promote the R&D of raw materials and material application, increase the investment in R&D of high grade oriented electrical steel, and steadily improve the performance and quality of oriented electrical steel of PTTX.

(2) The transition from old to new energy systems has placed focus of many countries on the stability and reliability of their energy systems and energy supply. Facing the market opportunities supported by the international policies, PTTX pays very close attention to the market demand overseas. It has obtained the recognition of overseas clients from Europe, the Middle East, South America, North Africa, Southeast Asia, etc. with its high-performance products. In the future, PTTX will accelerate the internationalization of enterprise standards. It will endeavor to build its overseas marketing network and continue to expand the influence of the PTTX brand image globally.

(3) PTTX will continuously implement the green development strategy. With the value of innovation as the first development force, PTTX will vigorously promote the transformer core application technology to a new level. By adhering to intelligent production and efficient production, PTTX strives to promote the intelligent trans-formation of the whole industry.

Metal Enclosed Electrical Bus – The Lifeline to the Transformer: What You Should Know and Why It's Important to Your Bottom Line



by **Mohsen Tarassoly**

Most of us know what happens when a catastrophic event occurs at a transformer; power distribution comes to a grinding halt and plant personnel scramble into action to assess the damage and try to piece together the root cause in order to bring the system back to full operation as quickly as possible. However, what is almost always unexpected, is the logistics of replacing damaged electrical bus duct, an often-overlooked system critical component spanning from the generator to the main transformer, carrying the system's full current. When a failure occurs, and the electrical bus duct is impacted, the entire energy producing system shuts down until the components and its appendices are repaired or replaced. The unplanned downtime often results in the revenue loss of hundreds of thousands of dollars while the plant isn't generating power.

Metal enclosed electrical bus duct is custom designed and built specific to each plant's specific electrical parameters. It has no moving parts. It also has no redundancy, despite it being a critical component in the overall generation system. Understanding the bus type connected to your transformer and the standard by which the bus is designed, is important. While there are many standards that cover different aspects of electrical bus duct, the current standard followed by all U.S. bus manufacturers is IEEE C37.23-2015. This standard supports four types of bus designs: Isolated Phase Bus (IPB), Segregated Phase Bus (Seg), Non-Segregated Phase Bus (Non-Seg), and Cable Bus. Most generators delivering current in the voltage range of 15 kV to 38 kV will have IPB installed. This doesn't mean you won't see systems connected with Cable Bus or Non-Seg Bus; it simply means IPB is the preferred bus to use. The main difference between IPB and the other bus types, is how the bus functions. Made primarily from

Maintaining electrical bus is just as important as maintaining your generator and transformer.

aluminum, each phase conductor of IPB is housed inside its own enclosure with air space separating each phase. Assembled enclosure and conductor sections are welded together in the field except at termination to the major equipment where bolted flexible connectors are used. IPB design is also referred to as zero flux design since once energized, induced current from the conductor, flows through the housing, in the opposite direction from the phase current producing a magnetic field in the enclosure opposite to the conductor's canceling each other out. Additionally, the forces created between conductors

Photo: Electrical Builders

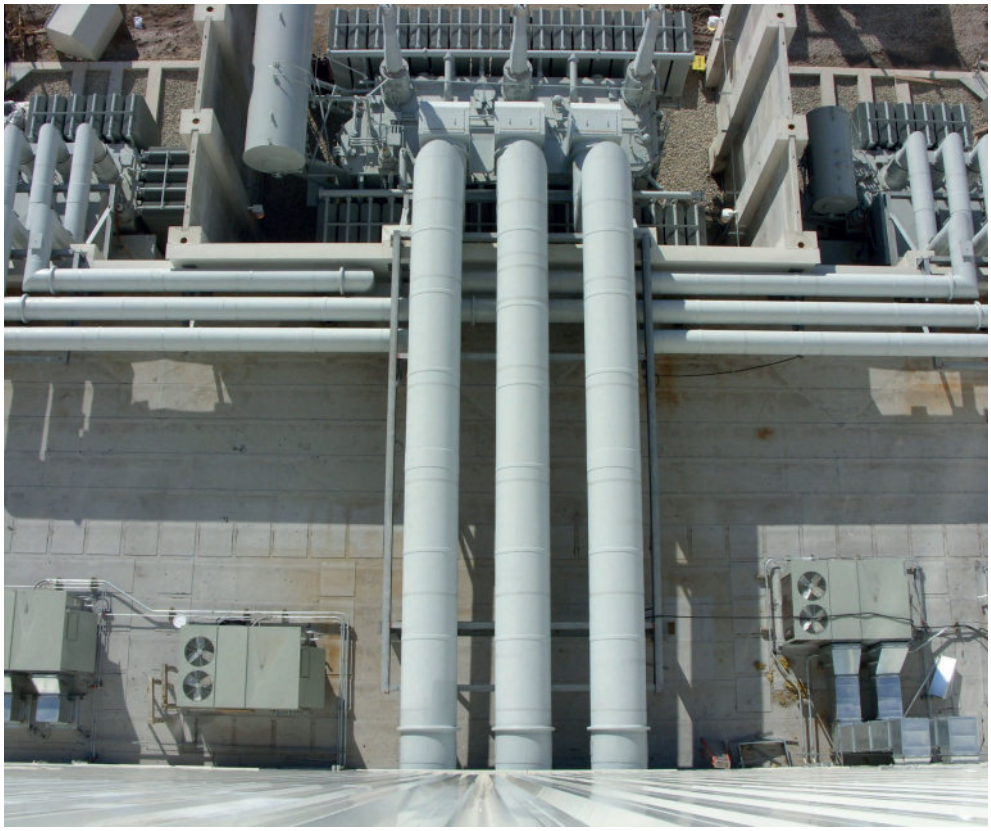


Mohsen Tarassoly is the Sales Engineer Director at Electrical Builders, Inc. (EBI). Mr. Tarassoly is an electrical engineer, earning his EE degree from Penn State. He has over 30 years of experience in both the domestic and international power industry working with most major utilities, EPCs, and engineering entities. His experience includes executive management roles with some of the largest OEM manufacturers of Isolated Phase Bus, Non-Segregated, and Segregated Phase Bus systems, including Powell/Delta Unibus and Technibus/ABB.

When a failure occurs, and the electrical bus duct is impacted, the entire energy producing system shuts down until the components and its appendices are repaired or replaced. The unplanned downtime often results in the revenue loss of hundreds of thousands of dollars while the plant isn't generating power.

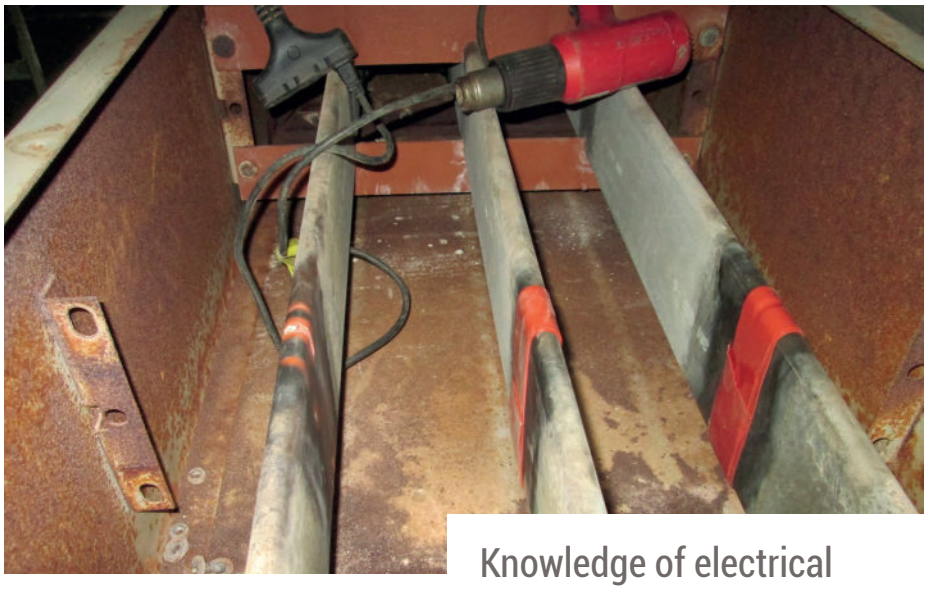
during a short circuit event will be significantly reduced. All other bus types produce very little induced current by the conductors, resulting in minimal magnetic fields in the enclosure. In short, the advantages of using continuously welded IPB are minimizing phase-to-phase faults, eliminating proximity effect for extra forces and heating, personnel protection (safe to the touch), and pliability. These factors make IPB the preferred bus design of choice for power generation.

Regardless of type, each bus electrical bus system is unique, and custom designed for each plant. While all bus manufactures must comply with the same IEEE design standards, each manufacture has their own specific method of constructing bus, which is unique to their company. However, what makes the bus a highly customized product, aside from meeting the plant's specific electrical profile, is the bus layout from the generator to the main step-up transformer. The electrical bus system must weave through the plant and accommodate the changing elevations, twists, turns, connections to various cubicles, etc., all while maintaining the appropriate clearances and navigating through possible space constraints. When the bus meets at the transformer, the bus to transformer termination arrangement is housed in a customized aluminum compartment, also referred to as the "doghouse". The doghouse contains the connections to the transformer bushings, all terminations typically using copper flexible connectors, rigid Copper adapter bars, and is bolted to the transformer face or top depending on the bushing orientation and in consideration of the required clearance to the high voltage side. As such, it is subsequently critical that the transformer termination configurations are designed appropriately to accommodate the fit up to both IPB and low voltage bushings of the transformer. For these reasons, when a failure occurs or transformer change-out is required, rarely is "like-for-like" replacement equipment readily available. Even when a "like-for-like" is planned, history and experience demonstrate that existing equipment conditions and environmental factors nearly always result in necessary bus modifications, fabrication of replacement components, transformer termination re-configuration, and proper assessment, planning and installation by an experienced bus duct service provider. All of these aspects are critical to minimize downtime and ensure safe and efficient return to service.



Even though the metal enclosed bus system is an integral component of the generation system, many engineers and plant maintenance personnel have limited awareness and experience of bus duct design, required maintenance procedures and frequencies, and best practices for transformer change-outs. This type of knowledge and expertise is unique and typically not covered in college curriculums, including engineering. This is one of the many reasons why the electrical bus system is often neglected and an afterthought when developing most contingency plans. When the unexpected occurs and the bus system is impacted, often, plant personnel don't know who to call for repairs or where to find replacement parts. This causes further delays and ultimately, impacts the bottom line. Some plants are so unprepared they mistakenly hire contractors who are unqualified to handle bus duct maintenance and repairs, putting the entire system and those around it at further risk. Partnering with a proven and experienced bus duct contractor to develop a proactive emergency service and repair plan is critical to extend the life of the plant's critical assets and is highly recommended as a best practice approach for leading power generation utilities.

Unfortunately, the pandemic has introduced further challenges. Several experienced personnel close to retirement have opted to leave their long-standing positions, oftentimes without sufficient onboard training for those taking over their roles. This has resulted in knowledge and data transfer loss. Incoming replacement personnel often must go to great extent to find and collect system critical component data and history. Even when this information is located, often, crucial information is missing, illegible, or inaccurate. Further complicating the issue, the need to identify the right parts, and dealing with lead-times on replacement parts and materials that have been significantly extended due to decreased production and availability as a result from the pandemic. These pitfalls result in inaccurate RFQs, unforeseen change orders and major project delays. Worse yet, if the plant encounters an unplanned outage or failure, these pitfalls will impact how quickly the plant can get back online.



Unfortunately, a growing number of plants have adapted a "run-to-failure" or "reactive" maintenance and repair approach. Compared to a "proactive" maintenance strategy, the reactive strategy appears to be less costly on the surface but waiting until something fails is a big gamble, and a safety risk. A risk that can significantly lower efficiency and further aggravate what could be a smaller, preventable issue, complicating an already critical situation. Opting for a proactive maintenance strategy can contribute significantly to the company's profit and losses (P&L) and certainly the opposite is true if an unplanned outage or catastrophic failure occurs. In fact, statistics have shown that a run-to-failure (reactive) maintenance strategy can cost 2-5 times as much as implementing a routine proactive, preventative maintenance schedule. In some cases, these numbers can be significantly higher (up to 10-15 times) with a much larger impact to the bottom if the failure occurs during peak power production schedules, when the generation system is being pushed to the limit and indirect costs are introduced into the mix. As such, the need for having an iron clad contingency and proactive, preventative maintenance plan has never been more prevalent.

Industry best practice recommends that "offline" bus duct inspection and maintenance to be performed annually at every scheduled plant outage, or at a minimum of every 18-24 months. However, over the past few years, there has been a strong movement in the power generation industry for digitalization and the ability to be able to monitor the systems' critical assets online as an early warning tool. Different technologies such as Electromagnetic, Infrared, Acoustic, Ultrasonic, etc., have been utilized initially for transformers and generators and extended more recently for bus systems. In most cases, this has caused a misconception that offline bus duct inspection and maintenance can be postponed or ignored. The monitoring systems today primarily monitor for detection of partial discharge, corona, arcing, etc., but fall short of monitoring for presence of temperature elevation, moisture and humidity, degradation of components such as insulators, gaskets etc. The outcome of the monitoring system usually represents some non-definitive "value" requiring further interpretation. A well-planned

Knowledge of electrical bus duct design and maintenance best practices is unique and not taught in any college curriculums, including engineering.

Photo: Electrical Builders



Over the past few years, there has been a strong movement in the power generation for utilization of online monitoring options, adding to the misconception that offline inspection maintenance can be post-poned, which can be a costly decision.

and comprehensive offline visual inspection can eliminate these uncertainties and can identify the source of issues as well as offer a permanent fix. Employing online monitoring system also cause plants to divide their budgets across two activities with partial results, versus one that provides certain results (offline inspection).

It is important for leading utilities to partner with a proven and experienced bus duct contractor they can rely on to proactively manage these critical electrical assets on their behalf. This approach results in less down time, increased operational efficiency and safety, and is the key in preventing a bus duct failure.

A thorough offline inspection can identify, with certainty, many things; including but not limited to poor installation or system design, cracked insulators, localized overheating, corona/arcing, condensation/water intrusion, loose connections, loose/ missing/inappropriate hardware, dust/dirt build up, debris/foreign material, improper grounding, cracked weld joints, poor or inadequate insulation, lack of proper silver plating, etc. Once these abnormalities are discovered, proper repairs and/or upgrades can be performed to ensure the system is running at optimal condition.

If your plant is currently planning an outage, or transformer change-out, don't overlook including your electrical bus duct system in your plant's fleet maintenance plan. Maintaining electrical bus is just as important as maintaining your generator and transformer. Routine preventative maintenance is not only a cost-effective way to extend the life of your electrical assets, but also a critical task in minimizing the risk of a forced outage and avoiding bodily harm to onsite personnel. Identifying the right partner to proactively maintain, service, and repair your electrical bus duct equipment, in addition to being your turnkey solutions provider, is critical to operational success and the key to plant sustainability.







Southern Company Goes Touchless™ to Reduce On-Site Transformer Inspections



Figure 1
IM500 Quick Mount installed on Southern Company transformer.



1. H1 Arrestor
2. H2 Arrestor
3. H3 Arrestor
4. H1 Bushing
5. H2 Bushing
6. H3 Bushing
7. X0 Bushing
8. X1 Bushing
9. X2 Bushing
10. X3 Bushing
11. X1 Arrestor
12. X2 Arrestor
13. X3 Arrestor
14. H1 Connection
15. H2 Connection
16. H3 Connection
17. X1 Bus
18. X2 Bus
19. X3 Bus
20. Load Tap Changer
21. Main Tank
22. Radiator (Inner)
23. Radiator (Outer)
24. X1 Connection
25. X2 Connection
26. X3 Connection

Figure 2
The points to be monitored on the transformer were identified

The Challenge

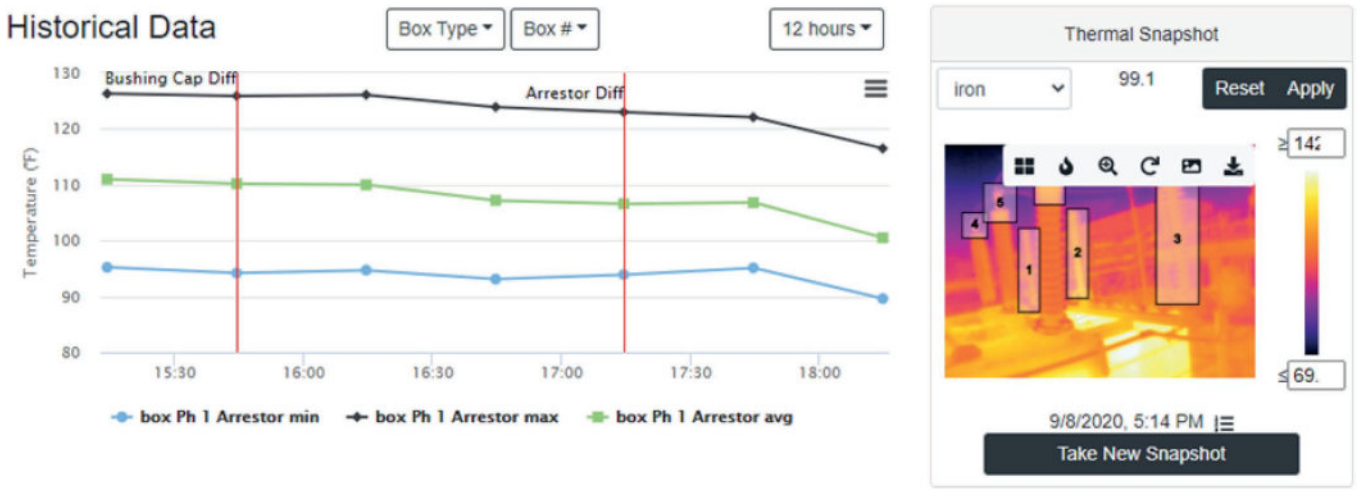
Large utilities maintain hundreds of substations with multiple transformers at each site. On site inspections cost utilities time, travel and they often must take planned outages to make sure the inspection can be done safely. It may take years for a utility to get through their whole fleet and by the time they do, its time to start the process again. These single point in time inspections can miss problems that can crop up in between the inspection cycles. With the advancement of sensor and communications technology, utilities can economically install automated, continuous monitoring systems to improve safety, reduce costs due to manual inspections and increase the early detection of potential failures.

With the advancement of sensor and communications technology, utilities can economically install automated, continuous monitoring systems to improve safety, reduce costs due to manual inspections and increase the early detection of potential failures.

Systems With Intelligence worked closely with Southern Company to develop an IM500 mounting system for their transformers. Due to the large number of transformers to be monitored, Southern Company wanted to minimize the sensor installation time and complexity so the project could be rolled out as quickly and economically as possible.

Background

Southern Company's goal was to find a way to extend on-site transformer inspection cycles more than 200% by deploying a remote monitoring solution that could provide transformer health data on a continuous basis. They were already deploying online Dissolved Gas Monitoring and Bushing monitoring, but a gap existed with the lack of infrared monitoring. Instead of doing periodic on-site visual and thermal checks, Southern Company wanted to have up to date and continuous information on the health of their transformers. Southern Company identified all the points on the transformer they wanted to monitor with the intent of integrating the thermal data into their Condition Based Maintenance system. Due to the large number of transformers to be monitored, Southern Company wanted to minimize the sensor installation time and complexity so the project could be rolled out as quickly and economically as possible. The goal was a product that would enable two men to install the system on multiple transformers in one day without an outage.



The IM500 Module is an IoT sensor with onboard thermal and visual images and built-in wireless communications.

An IM500 takes temperature readings on live systems and will detect overheating bushings, lightning arresters, load tap changers, cooling systems, main tank and other transformer subsystems.

Project Requirements

Southern Company had clear ideas about the solution they wanted to implement to achieve their goals of optimizing maintenance plans.

Thermal Monitoring of Critical Points – the maintenance team identified the critical points on the transformer that they wanted to thermally monitor. A thermal sensor could monitor multiple transformer subsystems and do the job of individual, specialized sensors. It had to provide continuous temperature monitoring of these points to provide an asset health profile of the transformer and its subsystems.

Ease of Installation – due to the number of transformers that Southern Company planned to deploy the monitoring system on, they needed an installation that didn't require digging for poles or cables. Substation excavations are time consuming and costly, so the mounting system had to self-supporting, be powered from the AC or DC supply already present inside the transformer wiring compartment and the sensor had to have wireless communication and low power consumption. Due to the strong storms that pass through the region, the mounting system had to withstand up to Category 2 winds.

Network Security – the sensor, cloud dashboard and data storage had to be secure and isolated from the Southern Company network. The equipment provider had to pass a comprehensive third-party vendor risk assessment for data security and application change management.

Data Integration – the data gathered from the sensor had to be integrated in the OSIsoft Pi system so it could be tied in with Southern Company's asset management, operations, and maintenance applications.

Photo: Systems with Intelligence

Latest Data

Timestamp	Box	Minimum	Maximum	Average
9/8/2020, 6:14 PM	Ph 1 Arrestor	89.6	116.5	100.5
9/8/2020, 6:14 PM	Ph 2 Arrestor	85.6	117.4	102.8
9/8/2020, 6:14 PM	Ph 3 Arrestor	80.8	106.1	99.3
9/8/2020, 6:14 PM	Ph 1 Bushing cap	82.9	107.1	90.1
9/8/2020, 6:14 PM	Ph 2 Bushing Cap	74.8	108.9	88
9/8/2020, 6:14 PM	Ph 3 Bushing Cap	67.6	111.3	91.7

Visual Snapshot



9/8/2020, 2:12 PM

Take New Snapshot

Figure 3
Comprehensive dashboard provides status, trending and visualization information

The Solution

The IM500 Module is an IoT sensor with onboard thermal and visual images and built-in wireless communications. An IM500 takes temperature readings on live systems and will detect overheating bushings, lightning arresters, load tap changers, cooling systems, main tank and other transformer subsystems. Due to its small size and low power requirement, the IM500 can be installed quickly in areas to provide optimal line of site monitoring.

Systems With Intelligence worked closely with Southern Company to develop an IM500 mounting system for their transformers. The mounting system attaches directly onto the body of transformer with industrial strength magnets that are rated to withstand the operating temperatures of a power transformer. The system is designed with high strength fiberglass and a series of adjustable clamps that allow easy positioning and quick installation. The mounting system coupled with Southern Company's safety work rules enabled the installation on an energized transformer.

The IM500s are pre-programmed to take snapshots that give operators a visual and thermal view of the critical transformer subsystems. The thermal data is collected, stored and analyzed on a continuous basis. The connection to the SWI Cloud is authenticated and encrypted to ensure the safety and security of access to the device and data. The Systems With Intelligence dashboard provides a comprehensive view of the data providing graphs of the temperature points along with visual and thermal images. Alarms can be set in the dashboard with automated email alerts so operators and maintenance experts are alerted instantly if temperatures exceed the pre-set thresholds. The data and alarms can be retrieved directly from the SWI Cloud, allowing the utility to trend the data and use it in a condition-based maintenance program.

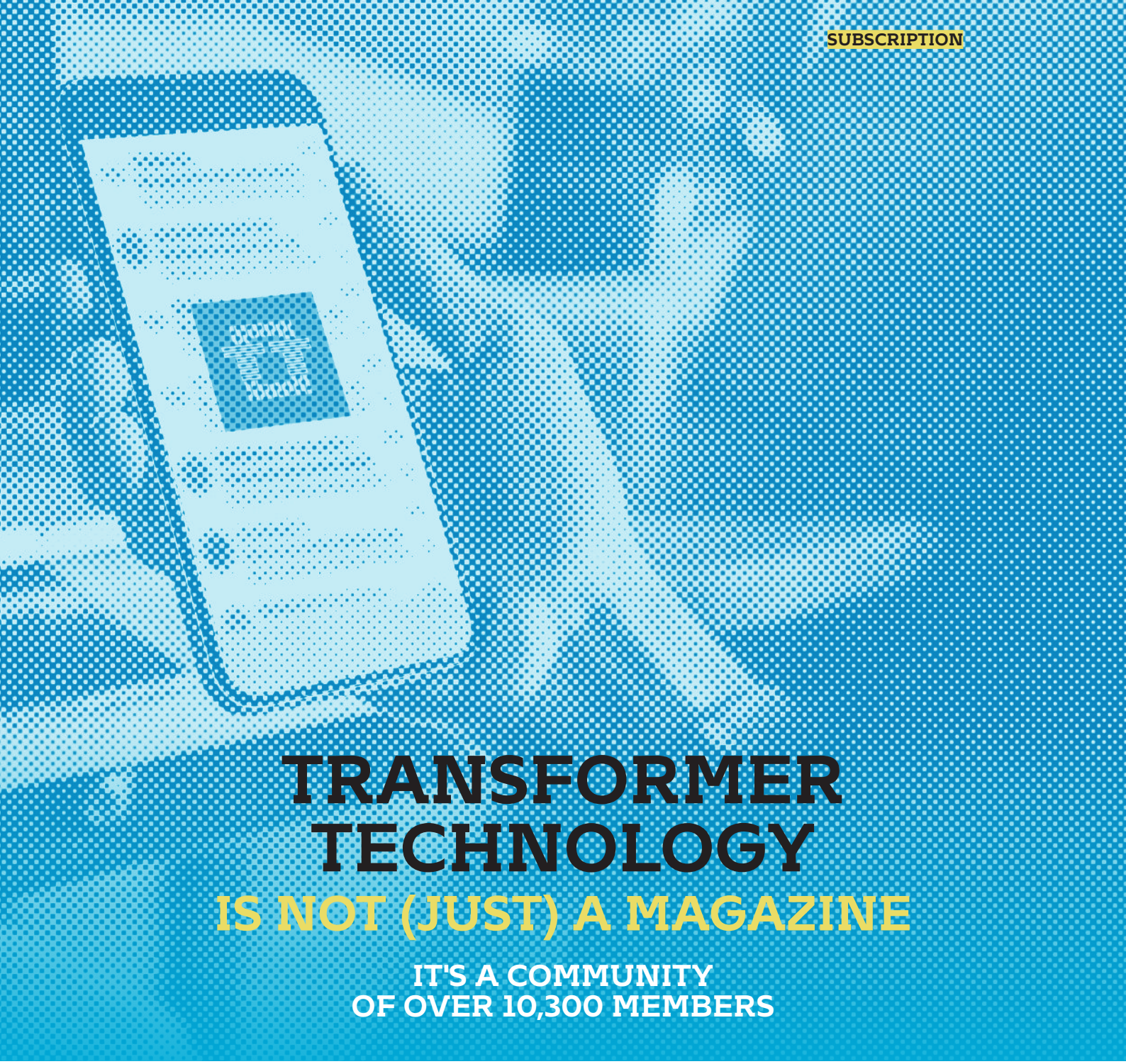
Summary

The IM500 allows Southern Company to perform remote, Touchless™ Inspections, with 24/7 monitoring on sites and equipment that would otherwise be time consuming and costly to inspect. The IM500 provides visual and thermal imaging, providing continuous and up to date health information on multiple transformer subsystems. The IM500 installs quickly and easily with the transformer Quick Mount, low voltage requirements and built-in communications. Temperature data is integrated with OSIsoft PI for further analysis, trending and input to asset management applications. Continuous thermal monitoring ultimately improves utility safety and reliability while reducing maintenance costs.

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Power System Technology: The Solid State Revolution

While we introduced Power Systems Technology in this issue, we expand our content in October with an issue on the Solid State Revolution that is happening in every industry as we move from electro-mechanical systems to solid state technology. Interviews with Prabhat Jain, CEO of Virginia and Georgia Transformer; Wilfried Breuer, Managing Director of MR and Dr. Denis Phares, CEO of Dragonfly Energy will resonate with these changes. It was quite a time this month gathering insights from these incredible thought leaders who are at the pinnacle of change.

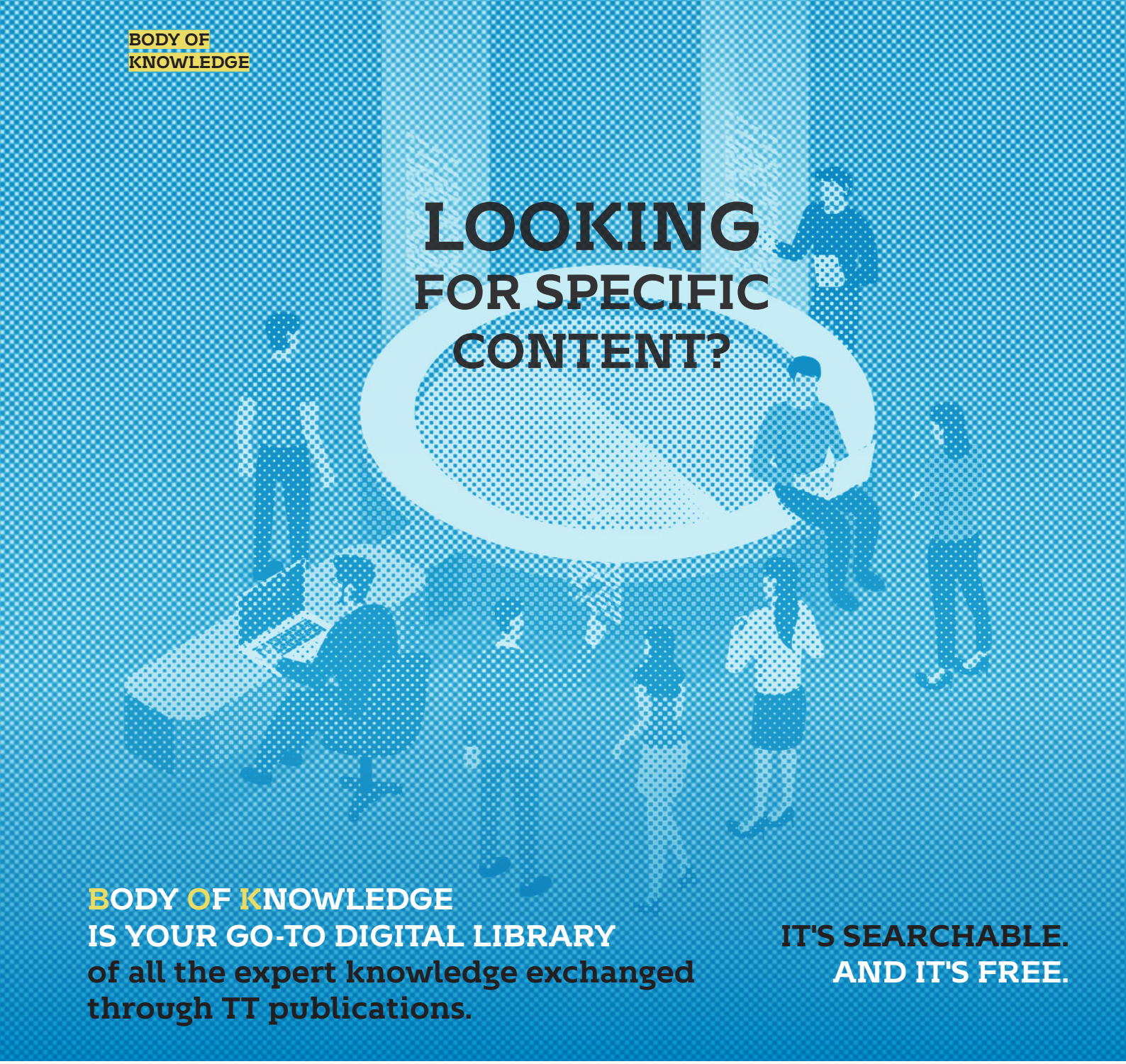
But what would an October issue be without focusing on bushings, so once again we have featured content from some of the industry's finest subject matter experts (SMEs). We also introduce a new form of content that we call Perspectives, which are short form articles of 500 to 800 words on one or two specific topics. This allows us to provide even more great content on the themes and topics of each issue. It can be intimidating trying to come up with an article of 1800 to 2200 words, which are what we ask for in our Featured Articles, when all of our SMEs are busy actually developing new technology or implementing current technology within their companies. We will balance Interviews, Feature Articles and Perspectives to bring you the best content we possibly can and we are tremendously excited that October begins this new development.

APC Media is growing thanks to all our SMEs, our great staff and most importantly, you our community. We have never been more bullish on the future of the power industry as we decarbonize and build a modern grid, capable of withstanding the dynamics that climate change, politics and technology are and will have. Become part of that change and share your knowledge with our community. We have organized a Technical Advisory Board (TAB) to direct our themes and topics of each issue and to create or edit content in their area of expertise. October will feature more about the TAB and the importance they will and are having on the future of APC Media.

Alan Ross, *Editor in Chief*

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