



TRANSFORMER TECHNOLOGY^{MAG}

Better Practices for Better Outcomes **From Specification to Commissioning**

Interview with Jon Trout, Manager of Transmission Operations Support, FirstEnergy
Interview with John Ulcar, Co-founder and Director, and Edson Fariello, CEO at Crosslink Technology
Interview with Patrick F. McAtarian, General Manager at Andax Industries

Women in Power Systems

We are delighted to announce that the June issue of Transformer Technology will not be about transformers at all. It will be the launch of a new APC Media Community - Women in Power Systems.

While we realize there are groups like Women in Engineering in IEEE, Women in Power in Cigre, Women in Reliability and Asset Management in [Reliabilityweb.com](https://reliabilityweb.com) and likely many more we are not even aware of, **Women in Power Systems will be unique.**

WPS as we call it, will not be commercially supported but will be **supported by a limited number of sponsors.** It will also rely heavily on interviews, presented as video-casts or podcasts on WPS website and other media channels; as well as profiles and impactful stories that will then be curated and featured, starting with our June issue.

WOMEN IN POWER SYSTEMS (WPS) is a community that advocates for women in all Power Systems roles by leading organizations to see and celebrate the benefits of women leading in their current and future positions.

Our Advisory Board, all women by the way, has determined the best approach and made it a point to include many other professional women within power industry, not just women engineers. Women in Procurement, Management, HR, Business Development, Executive Leadership, Marketing and a host of other professional women make up Women in Power Systems.

We believe the June curations will set a new standard for what a collaborative and informative community can be. Weekly features will be curated into our following 2021 issues as WPS Curations.

From that point forward, Transformer Technology will continue to build on its community just as Women in Power Systems does on its own community; both adhering to the high-quality standards that APC Media follows.

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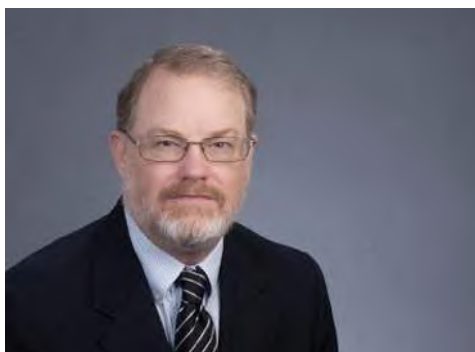
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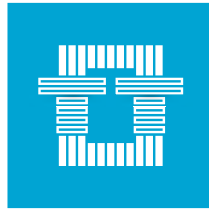
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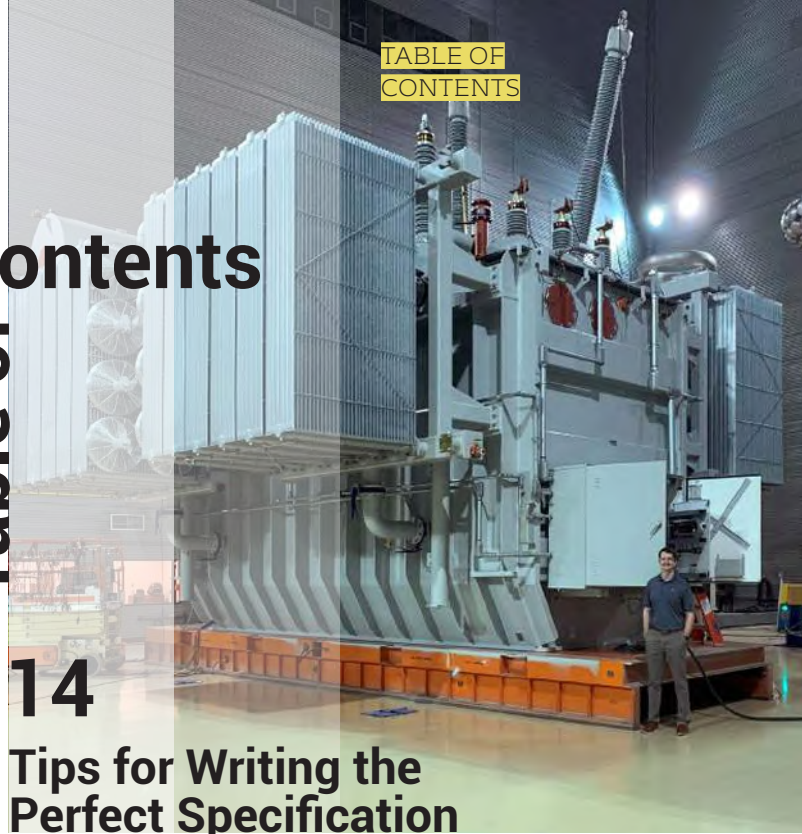
Tips for Writing the Perfect Specification

Writing a transformer specification for the first time can be a daunting task. This article should serve as a "getting started" guide on creating the perfect specification, breaking down the details into an easier way to think about writing a specification. It will touch on structure, IEEE standards, performance characteristics, core and coil design, external design and testing and commissioning.

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This short but very important article
answers five critical questions about
transformer grounding, which, when
done properly, can save lives.



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Solving Movers for the Transformer Industry





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Temperature Rise Test Corrections for Three-Winding Transformers with Axial Split-Windings

The split-winding arrangement in core-form power transformers requires special thermal design considerations. Presently, industry standards do not provide significant detail on the temperature rise test for these unique arrangements. This paper will demonstrate how to supplement the industry standards for this special transformer construction and some common problems that arise in practice.

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GFRP insulation components allow revisions to transformer design: How Durostone® CR contributes to compact design and resilient transformers



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Transformer Insulation (Quality) Matters

Many do not recognize the importance of specifying the insulation system and the vital role it plays in the attainment of the specification's objective. This article makes a great case that investing a few more dollars of cost by specifying a more robust and reliable insulation system reduces the total cost of ownership by adding life to the asset.

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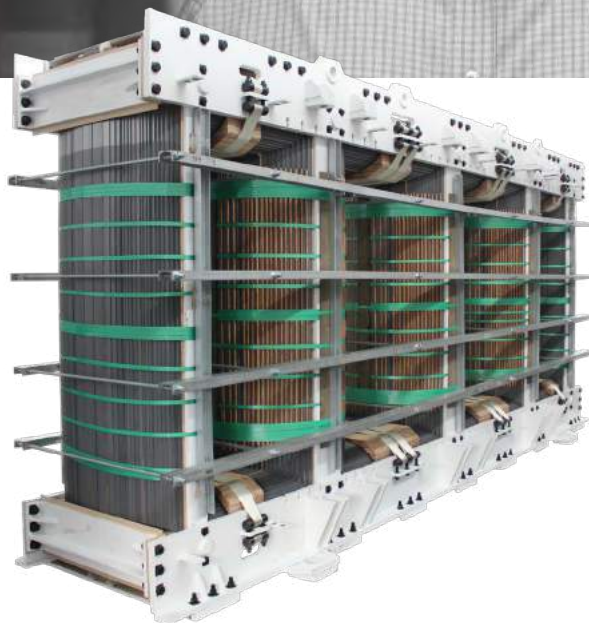
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Protection and Control Commissioning: Two Steps Forward, One Step Back

The energy industry is moving forward at warp speed on technological and infrastructure changes. A major gap has emerged among the resources that provide protection and control commissioning services on power systems, and it boils down to lack of training and system knowledge.

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Vibration and Noise Reduction of Transformers: PTTX's Artisan Spirit of "Daring to Be the First"



Dear Readers,

There has been a significant change in the past decade relating to specifications for transformer purchases. The pendulum has swung from a heavy reliance on engineering input to procurement-driven specifications. What does this mean for us engineers who used to be the final say on what was specified and where we were allowed, even encouraged, to work directly with potential bidders to develop the very best specifications? We had things our way for a long time.

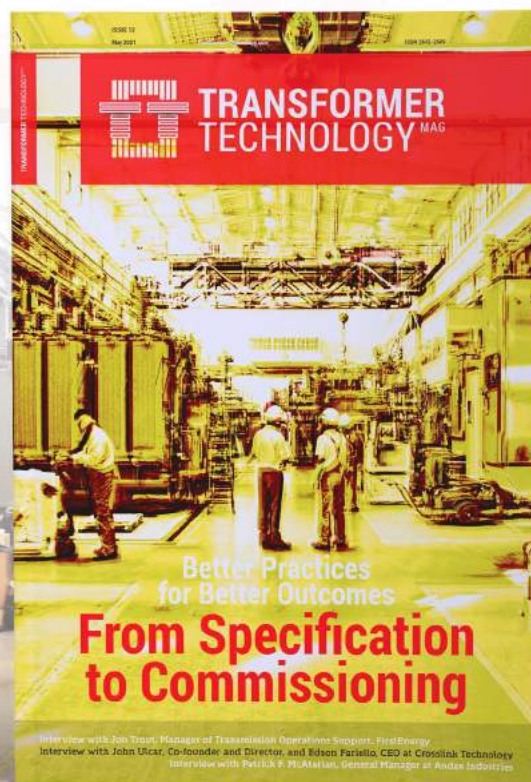
However, that came with a cost, with less regard for the actual cost of the asset and more focus on the application of the asset. In my world of reliability, that was great given that *all reliability begins in the design phase* - I cannot emphasize that enough. That is true of the assets like transformers, circuit breakers, cables etc., but it is also true for the entire system those assets make up. For substation reliability, every asset must meet a required specification that is compliant to the standard for reliability you demand of the system. When assets fail, the system fails.

More than likely, we may have over-engineered or overbuilt assets as a result. Robustness of transformers is legendary. Prior to becoming the President of the Electric Power Reliability Alliance (EPRA), I worked for SDMyers as the VP of Reliability and every year we celebrated the birthday of all of the transformers that we tested the previous year with a life of over 100 years.

Think about that! What other major asset can you name that has 100-year-old critical equipment? Not many, if any. This is what an engineering focus on design and specification creates.

But as the advancement of procurement systems and the advent of purchasing guidelines became more prevalent, cost cutting became the mantra of the day, and it still rules today. Try to meet with bidders on large asset purchases in a more commoditized marketplace, like transformers have become, and it is likely you won't be able to. I believe this creates a huge gap in specifications. Transformers are unique based on so many factors, such as footprint, application, ratings, clearances and a myriad of other factors, and it is a shame that the process of creating the specifications cannot take advantage of the tremendous knowledge and experience of the better OEMs. Low purchasing cost will not likely lead to the lowest Total Cost of Ownership (TCO), another major reliability principle, or create systems that are able to withstand significant analogies - weather events, grid resilience events and more.

However, I see the shift coming back to a point of equilibrium, with the better procurement professionals and systems addressing the need for more collaboration in the design and specifications processes. That balance will allow engineering to have a more important say in the process, without sacrificing value over cost. Value is TCO. Cost is not value.





In transformer design, the pendulum has swung from a heavy reliance on engineering input to procurement-driven specifications. As the advancement of procurement systems and the advent of purchasing guidelines became more prevalent, cost cutting became the mantra of the day, and it still rules today.

While most of our articles and interviews in this issue do not address this pendulum shift, they do approach specification, transportation and commissioning in a very special way. I am very proud of all of our authors and interviewees who are passionate and committed to meeting the needs of the practitioners, balancing the procurement requirements and presenting great content to be added to the Transformer Technology Body of Knowledge (BoK).

I am sure that you will enjoy this.

Alan M Ross
CRL, CMRP
Editor in Chief
Transformer Technology
Curator of the Community
President of EPRA



Alan M Ross



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AND KNOWLEDGE
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TO US**

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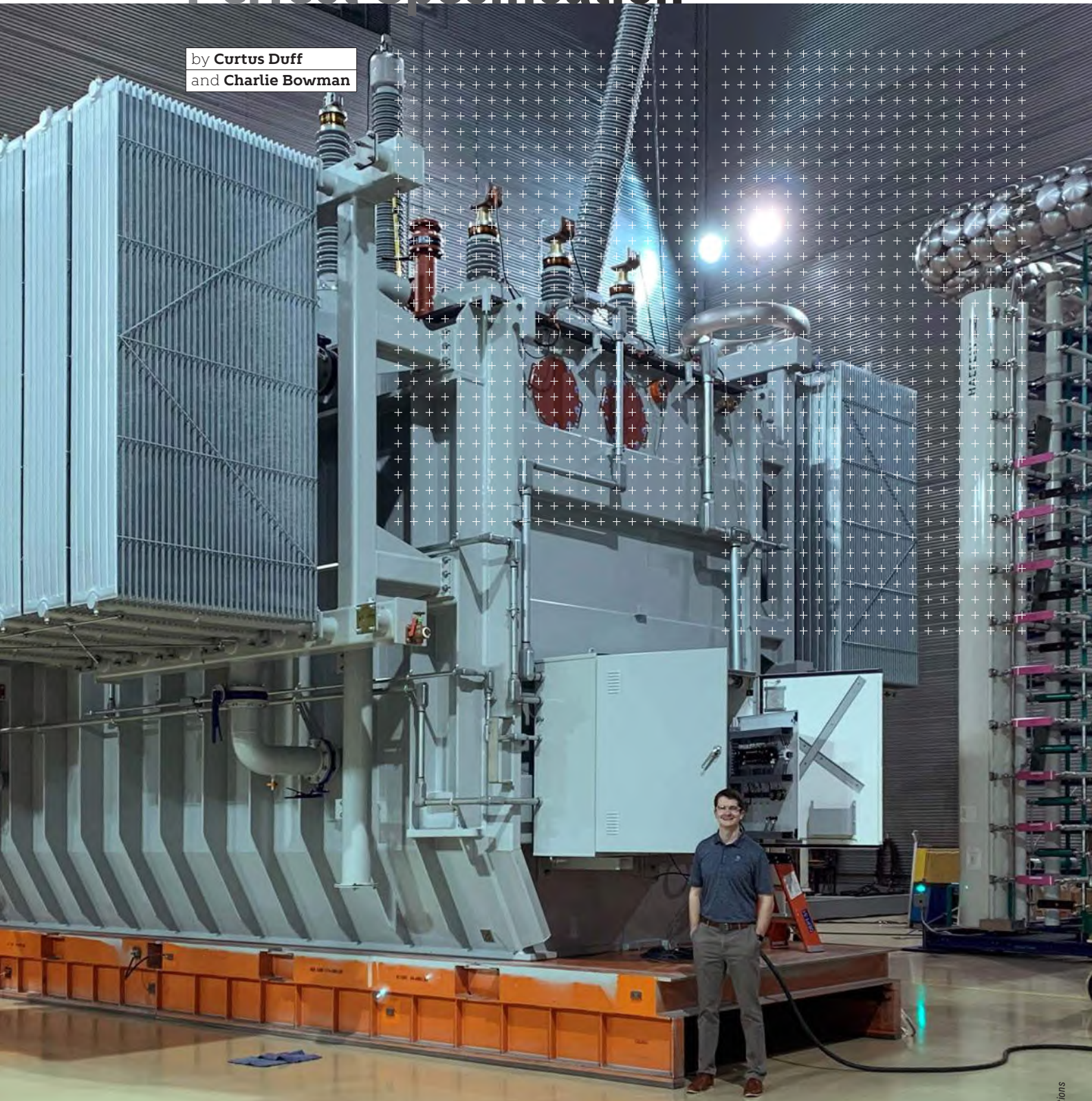


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Tips for Writing the Perfect Specification

by **Curtus Duff**
and **Charlie Bowman**



Because no rules exist, one thing to remember is that the perfect specification is the specification that results in the perfect transformer for your requirements and operating conditions.



Charlie Bowman is a Lead Mechanical Engineer at SPX Transformer Solutions where he manages the external design team. He received his Bachelor of Science in Mechanical Engineering from Purdue University in 2018. His first position out of school was with SPX Transformer Solutions in the Engineering Development Program, which led him to the current role he has held for just under a year. He enjoys golf and hiking with his wife in Pewaukee, Wisconsin.



Curtus Duff is an Electrical Design Engineer at SPX Transformer Solutions where he designs medium and large power transformers. He graduated from Purdue University in 2016 with a Bachelor of Science in Electrical Engineering. Upon graduation he started at SPX Transformer Solutions in the Engineering Development Program with six-month rotations each in Design, Testing, Manufacturing, and Application Engineering. Upon completion of the program in 2018, he joined the design team. He and his wife reside in Waukesha, Wisconsin where they enjoy finding small food markets to try cooking new foods. On the weekends he can be found mountain biking or skiing.

Do you need a transformer? If not today, then tomorrow. As the world ages and populations grow, the need for power—specifically, reliable power—grows with it. As infrastructure comes due for replacement and everything we own becomes electrified, this aging of equipment and additional load demand means the need for more transformers.

Writing a transformer specification for the first time can be a daunting task. Transformers come in all shapes, sizes and with a variety of features, and every utility has different requirements. The specification is the document that communicates those requirements to the transformer manufacturer. No rules exist for what should be in the specification, but an unlimited number of options do exist from which a utility can choose.

Specifications can run into topics deeper than you have time to read in this article. So, rather than trying to answer every question, this article should serve as a **“getting started” guide** on creating the perfect specification, breaking down the details into an easier way to think about writing a specification. It will touch on structure, IEEE standards, performance characteristics, core and coil design, external design and testing and commissioning.

Because no rules exist, one thing to remember is that the perfect specification is the specification that results in the perfect transformer for your requirements and operating conditions.

Structure

This one might seem obvious, but a good transformer specification needs structure. Any specification can have many parts, and a good specification keeps those parts organized. Break the specification down into pieces and have a table of contents in the beginning.

Transformer manufacturers receive a lot of bid opportunities and are usually under time constraints to bring a bid package your way. Having an organized specification is the best way to ensure that the bid process goes smoothly and the bid package offered by the manufacturer contains all of your requirements.

IEEE Standards

Conveniently for all of us, the transformer industry provides standards to guide us. Employing these standards helps ensure a manufacturer designs and builds reliable infrastructure. Many standards organizations exist globally, such as CSA, IEC and IEEE, and the applicable standards can vary depending on where you are located. In the United States, the IEEE PES Transformers Committee is your friend! Collective members throughout its over 100-year history have

worked together diligently to develop standards for all types of transformers and continue this work revising relevant standards as the needs arise. Referencing these standards for your own knowledge is a must, but referencing them in your specification is recommended, as well.

In the United States, the two main standards to reference are IEEE C57.12.00 [1] and C57.12.90 [2]. For some utilities, just referencing these standards might be enough. For others, additional detail may be

required. A good example of this is normal/usual service conditions versus actual service conditions. IEEE C57.12.00-2015 Section 4 states that normal conditions are a low of -20°C, a high of 40°C and an average of 30°C during any 24-hour period for ambient temperatures [1]. In most cases, these guidelines will be fine, but, if not, that is a piece of information your transformer manufacturer will need.

More than just service conditions, the standards touch on ratings,

Standards should be used as guidelines with variances communicated when needed. This strategy is a solid way to ensure you are acquiring a transformer that meets your exact needs.



Always consider the variety of items specified in the performance characteristics section and think about how they might impact cost.

construction, short circuit, testing and tolerances. While the standards cannot write a specification for you, they are a great starting point and should be referenced. If a particular part of the standard applies to your requirements, then quote it in your specification. If you need a variance from standards, state how so without being ambiguous. For example, IEEE C57.12.00-2015 Section 7 gives information on how to provide system characteristics for short circuit consideration [1]. If these system characteristics are not provided, the standard gives guidance for assumed system characteristics. If you need 110% pre-fault voltage and the assumption of an infinite bus, this will not be captured by the standard, and you will have to explicitly state this in your specification. For a low impedance unit, cost could be impacted significantly, so understanding what you are asking for is important!

In summary, standards should be used as guidelines with variances communicated when needed. This strategy is a solid way to ensure you are acquiring a transformer that meets your exact needs.

Performance Characteristics

Performance characteristics are likely the most important part of the specification. This section is usually found near the beginning of the spec and tells the manufacturer exactly what kind of transformer you are looking to purchase. Many decisions need to be made by the purchaser when going through all of the items that will be contained in the performance characteristics section. IEEE C57.12.00-2015 [1] Section 5 can help walk you through these components: phases, voltages, winding connections, MVAs, no load and load loss evaluations, impedance, insulation levels, etc.

For example, if dimensional limitations exist for delivering a large three-phase transformer to a mountainous area, perhaps a bank of three single-phase transformers would be a better choice. While a bank of three single-phase transformers might not be as cost

effective as a single three-phase transformer, it may be your only option. For another example, if the location in which the transformer is to be located falls within the range of normal service conditions, consider specifying the transformer as a 65°C rise unit. IEEE C57.12.00-2015 [1] Section 5, Clause 11, explains this. With the introduction of thermally upgraded paper insulation, 65°C rise is the new normal. Harking back to transformers of old, without the thermally upgraded paper insulation, they were specified as 55°C rise for average oil and average winding rise and a 65°C hot spot rise. Now these same transformers can be specified as 65°C and 80°C rise respectively. Notice that 65°C to 80°C is a change of 15°C. If you do decide to specify a 55°C rise unit, consider allowing 70°C for hot spot rise, as your unit is going to be built with thermally upgraded paper insulation. This will help bring down the cost of your transformer without sacrificing any loss of life.

Always consider the variety of items specified in the performance characteristics section and think about how they might impact cost. Ask yourself what is truly necessary for your particular situation. Regardless of what you decide, communicate your choices clearly to the manufacturer.

Core and Coil

For an electrical designer, the core and coil is the fun part! Like most engineering practices, designing the core and coil is a lovely game of tradeoffs for optimization. In particular, this is the part where the designer calculates the volts per turn. From the transformer equation $V/T = 4.44BAf$, the designer can vary the volts per turn by adding or subtracting turns from the high voltage and low voltage accordingly while maintaining the correct ratio for voltage transformation. What designers are controlling is the B – flux density (think no-load loss) and then adjusting the A – area of the core accordingly. This practice allows the design to hone in on an optimized amount of copper and core steel, thereby offering you a transformer at an optimal cost.

Of course, that is not the only thing electrical designers do. They also manage the kind of winding that is optimum in a given space, the turns per disc, strands per turn, tap changers, tapped windings, the strength of the windings for a short circuit fault, the dielectric clearances, the load and no-load losses, the impedance and much more. Many variables exist, and these variables should be considered levers of optimization for the designer.

Freedom for an electrical designer to make choices is what brings you an optimized transformer cost, and that is why manufacturers often encourage specification writers to consider carefully the limiting parameters he/she might include in a specification. While limiting parameters is unavoidable in some cases, such as when a transformer might need to fit through a tight place or, as a retrofit, need to be physically sized a certain way, in other cases, “designer’s choice” may be the best option. Specifying CTC only, a minimum radial dimension of a copper strand, exactly how taps must be arranged or a minimum key spacer thickness can lead to higher cost and, often, no real benefit. These are items that take away elements of a designer’s ability to give you an optimized design at an optimized price.

While you may have good reasons for including a variety of limiting parameters in your specification, understanding how these design parameters can impact cost is important as you evaluate whether or not they are critical to the application. As these levers of optimization are taken away from the electrical designer, designers have to make changes accordingly. These changes can end up resulting in a design that is not as optimized cost-wise as it could have been. Regardless, if what you are asking is possible, then it can be done. Make sure to clearly state your intentions so the designer understands what you are looking to receive. Depending on complexity, an open line of communication with your manufacturer may be necessary as the company starts the design process.

External Design (Tank, Accessories and Controls)

The tank design begins with any site dimensional limitations, shipping restrictions and oil preservation system requirements. These factors influence the cooling layout, drive equipment placement and overall unit footprint. Including site drawings and photos ensures no details are overlooked, especially if the design is a retrofit.

Accessories play a key role in how the user interacts with the transformer, and the possibilities for selection and placement are limitless! Explicit,

precise instructions on not only what accessories are necessary, but any preferences on vendor, configuration and segment placement, are important to include in your specification. If no preferences are indicated, the manufacturer will select and place equipment per IEEE and its own internal standards. While this equipment will undoubtedly be effective, it might not fit your preferences exactly. Examples of accessories include bushings, arresters, valves, gages, sensors and cooling fans. Any spare parts or future equipment provisions should also be included so they can be factored into the proposal and, subsequently, the order.

With the introduction of new devices and monitoring systems, control cabinets are more complex than ever. To make sure the controls design goes smoothly, include model-specific information for all preferred devices within the control box so proper wiring diagrams can be acquired. Possible devices could include electronic temperature monitors, LTC controllers, relays and terminal blocks. If any devices have preferred mounting locations within the control cabinet or wiring requirements, such as terminal style, those should also be noted.

Site environmental conditions should always be provided in detail as they



From core and coil to external design, the common thread is effective communication. Be clear and concise about your requirements and remember that good specifications are crafted over years with multiple inputs and revisions, all in the pursuit of acquiring the perfect transformer.

Any spare parts or future equipment provisions should also be included so they can be factored into the proposal and, subsequently, the order.

drive external clearances, accessory rating selection, control box enclosure design and equipment mounting. Examples include extreme altitudes, temperatures, pollution exposure, sound limitations or levels of seismic activity. Unless you are designing a substation for the first Mars settlement, odds are the manufacturer has seen your conditions before and can arrive at a solution that best fits your needs.

When considering external transformer design, writing an effective specification can be simple: focus on your needs. The manufacturer cannot tell you exactly what you need, as a multitude of factors drive those decisions. What the manufacturer needs is clear language describing all vital, non-negotiable requirements. Provide as much information as possible up front, free of contradictions. Disconnects between the specification and customer requirements can often lead to questions, miscommunication and additional costs for late changes in the design. If areas exist where you have no preferences, trust the manufacturer's expertise to fill in the gaps between your needs to arrive at an optimized external transformer design.

Testing and Commissioning

Testing and commissioning are the final pieces to bringing that new transformer to its pad in your substation. Testing includes the final quality checks before the transformer gets wired up and fired up after commissioning. Once again, the IEEE makes testing easy in C57.12.00 and C57.12.90 [1], [2]. Reference C57.12.00, Table 17, to see all standard tests for Class 1 and Class 2 transformers. Then reference C57.12.90 to get more information on each test. You can use the IEEE standard list of tests in your specification and then make adjustments according to your particular needs.

You might be looking for your transformer manufacturer to handle freight, rigging and installation as well, which means shipping the transformer to you, placing the transformer on your pad and installing it according to the manufacturer's—and your—requirements. Installation typically involves a set of field tests to verify the condition of the transformer post-shipping then placing the transformer on your pad. For these items, supplying as much information about the

substation as possible is important to ensure a successful installation. Details could include an ideal route to the substation and layout drawings of the actual substation and/or pad on which the transformer will sit. The more information you provide, the more accurate a quote you will receive. Complete information will also allow for a more comprehensive plan to get your transformer hooked up as fast as possible with no delays.

Conclusion

An exorbitant amount of factors need to be considered—and documented—when writing a full transformer specification. While the aforementioned tips and tricks may be useful, they merely scratch the surface of what it takes to finalize a full specification. From core and coil to external design, the common thread is effective communication. Be clear and concise about your requirements and remember that good specifications are crafted over years with multiple inputs and revisions, all in the pursuit of acquiring the perfect transformer.

As a final example as to why transformer specifications are so important, note that it is not uncommon for transformers in rural areas to require additional external clearances on the cover for local wildlife. If you are one of those utilities needing to adjust for this, make sure you tell the transformer manufacturer whether you expect the critter landing on the cover to be a squirrel or a stork!

References

- [1] IEEE C57.12.00-2015 – IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
- [2] IEEE PC57.12.90 - IEEE Draft Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers



Photo: SPX Transformer Solutions



TOTUS

TOTAL TRANSFORMER MONITORING

TOTUS is the only system that can diagnose arcing in a transformer

The Challenge for Asset Managers

DGA is typically used to detect discharge of high energy (D2), with Acetylene being the primary marker. The challenge for asset managers is little visibility on when an arc has occurred and in which phase and winding, as well as no tracking on the number of arcing events, thus making difficult to choose and plan the best remedial action.

How Does TOTUS Total Transformer Monitoring Drive Value?

Whereas other monitors can provide basic information detecting acetylene in the transformer, TOTUS delves deeper into arcing activities, **identifying the phase and winding, as well as visibility on the number of arcing events**. TOTUS gives asset managers the ability to correlate data to generate a deeper understanding of changes in the transformer, driving accurate decision making about asset health.

About TOTUS

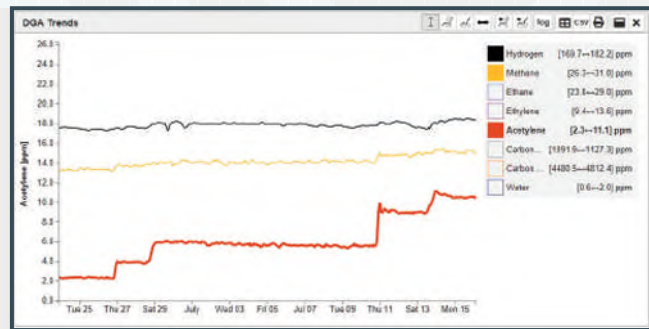
TOTUS is the world's FIRST and ONLY TOTAL TRANSFORMER MONITOR with market leading specifications and is the ONLY system to combine DGA, Partial Discharge, Bushing Monitoring, Through Fault Currents and Predictive Analytics into a single system.



camlin energy

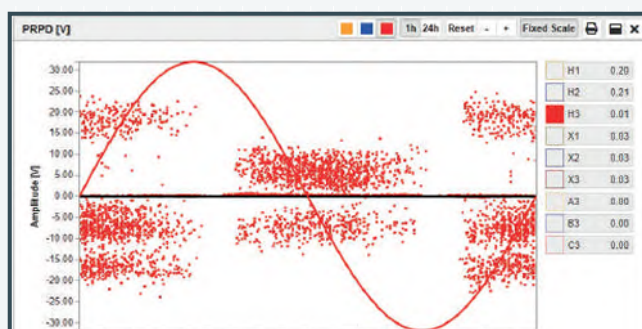
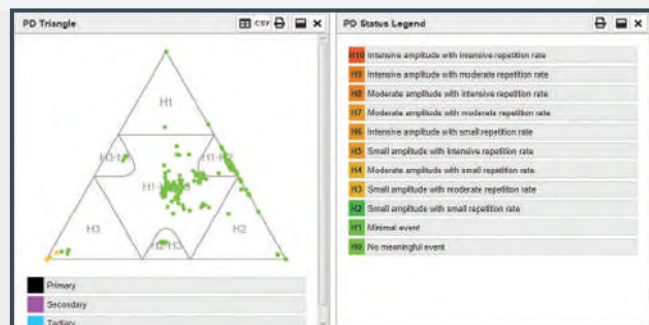
Data

- 1. Detect** periodic step increase of acetylene – Genuine internal arcing or something else



- 2. Confirm** with PD Monitor – High Energy Events detected at each C2H2 increase

- 3. Locate** arcing winding & phase – PD Triangle shows HV winding phase H3



- 4. Identify** the defect failure – PD pattern shows floating object in transformer

Decision



Inspect transformer focusing immediately on phase H3 at HV side to find evidences of discharges and floating potential objects

Jon Trout

Manager of Transmission Operations
Support, FirstEnergy

Interview with **Jon Trout**





Specifications are not static documents. They are living and they need to change periodically to keep up with technology changes and material enhancements.

Jon Trout is Manager of Transmission Operations Support for FirstEnergy, an electric utility headquartered in Akron, Ohio, and a contributing editor of Transformer Technology.

Jon Trout is Manager of Transmission Operations Support for FirstEnergy, an electric utility headquartered in Akron, Ohio, and a contributing editor of Transformer Technology. Jon previously worked with transformer manufacturers to supply FirstEnergy with reliable electric power system equipment and has experienced many changes in the world of transformer technology over the years. For this issue dedicated to specifications, commissioning and transportation, Jon shared some of his experiential knowledge in a Tech Talk with our Editor in Chief, Alan Ross. This interview is an excerpt from that.

Alan Ross: I welcome my guest and a friend – Jon Trout of FirstEnergy, and a contributing editor of Transformer Technology.

Jon Trout: Thank you, Alan.

AR Jon, experiential knowledge is really something that Transformer Technology promotes, and you certainly have had a tremendous amount of that. One of the first things you did when you were at FirstEnergy is develop specifications for transformers. You had to look at the past, the present, and the future. In your past experience when you were developing specs, what were the most important aspects that you would look at?

JT You mentioned a little bit of it – looking back at the past to see what has worked well, and then looking forward to the future. I will break it down to two things.

The first is, if you are creating a specification, you want to set clear expectations. There are many manufacturers out there that make transformers for many different applications. You need to be able to define what you need the transformer to do, how you are going to apply it to your particular scenario, and what capabilities it needs to have, so that the manufacturer can understand your particular need and provide you with the best fit for your application. This also includes considerations like physical constraints: Do you have a limited space for this particular unit? Is it next to a building? Does it have to fit in a position where an old transformer came out?

I use the following analogy: if you go to a car dealer and tell them you need a vehicle, you could end up with anything. But if you tell them that you work construction, they are not

going to try to sell you a small economy vehicle. They are going to sell you a truck, which is what you need. So, you need to tell the manufacturer what you need the transformer to do, so that it meets your expectations.

The second thing is long term planning. When you purchase a transformer, you intend to keep it for quite a while. And that entails a lot of things including your capabilities, the warehousing, your spare parts inventory and everything that is required to maintain that transformer over the next 25 to 50 years. Also, you need to specify to the manufacturer the type of equipment you need on a transformer because you may already have spares for some of the equipment you plan to have on your transformer.

Another important consideration is the kind of maintenance you plan for the unit. For example, if you are planning to do routine full inspections that require draining the oil out, the manufacturer needs to know how the oil will be drained so that they can make sure you can do your inspection. Do you want valves on your radiators in case one starts leaking, so you can replace a single radiator as opposed to having to cut off the whole thing? These are the specifications you need to provide for your manufacturer when you think long term and how you intend to maintain the transformer over the course of its life.

AR Design, Operate, Maintain and then Lifecycle planning – they are the four stages of reliability and they fit right in with what you are talking about. The reliability of electrical systems starts at design, it all starts with specs.

You and I have been involved in a lot of situations at different points in our careers, and



Looking back at the past to see what has worked well, and then looking forward to the future are the two most important aspects to look at when developing transformer specs.



sometimes, we would help somebody develop specs, only for them to go out and take them to a marketplace and buy low bid. In the utility world, you are going to go out in a bid base.

JT Usually, there is a bid process that goes along with purchasing transformers. There is often an established vendor list, but you are most likely always going to bid the transformer purchase.

AR Chuck Baker, one of our authors and contributors, was on a recent EPRA Forum talking about services and maintenance. He mentioned the same thing you did - that you had to make sure you get the scope right.

As he said, many times the supplier that is going to bid on a transformer can look over your specifications and help you develop better ones. Was there a time, or a relationship, where you asked somebody to check if you were missing anything in the scope of your specs?

JT Yes, there are plenty of consultants who can provide that support and help you develop your specifications. I have done some of that in the past for companies. Also, there is feedback from manufacturers. They will ask questions about your specs and say: We do this slightly differently. Here is how we may handle this particular area of what you are requesting. Is that OK?

Specifications are not static documents. They are living and they need to change periodically to keep up with technology changes and material enhancements. So, the feedback from the manufacturer will provide insight into what they do and how they do it, and why they think it is an excellent way to do it. And then it is up to you as the purchaser to validate whether you can accept a deviation from your spec or not, which usually doesn't happen during the bidding process. That is usually because you can establish the relationship with the manufacturer.

As a specification writer, you ought to be reviewing your spec periodically to make sure that it is still what you want it to be and to see if there are any changes you need to make to keep up with enhancements in technology or processes.

AR I want to go to another thing that I know you are experienced in, and that is plant inspections. You have finally made the specs, the bid is out, you got the bid. Now the manufacturer is starting to build the transformers and you are doing the different stages of inspection. Tell me a little bit about that from the perspective of purchasing people and the procurement people - what should they do? What should they hold the manufacturer accountable for? And what has been your experience with plant inspections?

JT Plant inspections are a great opportunity to interact directly with the actual manufacturing capabilities of whoever you have

chosen in your bid process. But once you get into the manufacturing stage and you are doing a plant inspection, you get to see the individual manufacturing processes - how they wind the coils, how they do tank manufacturing, how they do installation, how they route the leads around the transformer, etc.

All of this is vital to understanding the real capacity of the manufacturer. And most manufacturers would love to tell you all about their quality control processes. They enjoy talking about their plant and this is also the opportunity to build the relationship with the manufacturer. So, when doing a plant inspection, ask them how they track material and different components as they come from different areas of the factory to eventually come together into the transformer. They will love to tell you about that.

Another thing for you to think about is the layout of the facility, as this also contributes to getting quality products. Are messy, dirty manufacturing processes separate from the clean processes? For example, you would not want to have your winding room and your tank manufacturing areas right next to each other. Tank manufacturing, welding and cutting create a lot of debris, dust and dirt, and you want your windings as clean and crisp and pristine as possible. You will learn about their capacities from how they dry their coils, how they size them, etc.

Also, talk to the people in the factory and ask them about their experience - ask them how long they have been doing it, whether they love

A photograph of a large industrial transformer manufacturing facility. In the foreground, a worker wearing a blue shirt and a safety harness is working on a large, light-colored transformer component. The background shows a vast factory floor with various pieces of equipment, including a large orange overhead crane with the number '200/16' visible. The scene is well-lit, showing the scale of the manufacturing process.

Plant inspections are a great opportunity to interact directly with the actual manufacturing capabilities of whoever you have chosen in your bid process and to build the relationship with the manufacturer.



what they do and find out about their level of experience, specifically in three areas. First, the engineering group - you want to know how experienced they are in the design. Second, you want to know about the winding area. What is the experience level of the winders? This is really important as the winding area is one of the key areas of the transformer manufacturer. And thirdly, you want to know about the testing team. How experienced are they? Do they know the standards? Are they familiar with the standard that you are requiring the testing to be done to? Do they handle testing according to other standards, like IEC versus IEEE?

Once you have a good understanding of that, it will give you some confidence in the capabilities of the manufacturer, and help you grow that relationship.

AR You have just talked about that plant visit where you go out and do the inspection. There is now acceptance testing where you have to confirm that you accept the manufacturing process. The manufacturer has to transport the unit and you have to do commission testing before you install it. What goes on during acceptance testing?

JT That is a good question. It is important for the purchaser to understand what tests are relevant for them and they want to be present for. Not all tests are equally important. For example, for the wiring tests, you may be able to let the manufacturer handle them and just show you a test report of how they wired the control panel. On the other hand, lightning impulse and partial discharge tests are really valid and valuable to witness because that gives you an insight into how well the transformer is put together.

The key is to ask good questions about how the manufacturer set the test up. Make sure they understand what the testing standard is, whether it is IEEE or IEC, or whatever standard you are requiring. You want to make sure that they understand that standard and know how to set up the test. Also, you need to watch very carefully to make sure that the data they are getting matches the acceptance criteria in the standards that you have laid out.

This requires that you as the owner are familiar with what those standards say and how the results should come out. You have to be willing to push the manufacturer a little bit if things don't



or you ask the manufacturer to assume that responsibility, they need to know if there are any constraints. For example, if you are in a very mountainous area, you may have a situation where the only way to get to your location is through a railroad tunnel. The manufacturer needs to be informed of that because you would hate to have the transformer come down the railroad and hit the top of the tunnel - that is not a good day for anybody.

I will tell you one story. We had a situation where we bought a transformer, the manufacturer did a route-study and everything looked good. But there was a minor mistake in the route-study - they checked bridge heights in the center-lane, closest to the center of the highway. But the bridge had an arch on it. So, the transformer would have cleared in the center, but on the right lane where the bridge is slightly lower, it didn't clear, and it snapped a bushing off.

These are some of the concerns you need to be careful about and make sure that your route is well planned.

AR I would like to go into something that I know you are heavily involved in, and that is preparing the next generation.

You are now that bridge generation between my generation and the next. It must be an enormous challenge for you and an enormous amount of fun for you to be able to make a difference in generations. What are you doing in that sense right now?

look the way you expect, ask them to explain and have them show you how the results fit in with your expectations.

AR The last thing I want to talk about is the commissioning. What are some of the challenges that you have seen at the stage when the transformer comes in; when it is transported and commissioned? If the unit doesn't work or if it fails within a year, somebody is going to look at you as the final guy and ask what you did wrong. Whether it happens in the design, in the inspections, the testing, the transportation or the commissioning, you are going to get blamed for mistakes. In your experience, how did you address it? What kind of problems have you seen?

JT It goes back to the specs again. Because the transformer spends the vast majority of its life not moving, the time that it spends moving and is subject to damage is the transportation process. That is why you want to make sure that it is properly specified and is going to handle the voyage from the manufacturing facility to the designated site.

Depending on whether you as the owner take on the responsibility for the transportation





JT It is a great opportunity, Alan, as we look to the future. It is funny how quickly time passes when you feel like you are a brand-new engineer, and then all of a sudden, you blink and you realize you are mid-career. I see it as an opportunity to pass on knowledge to the next generation, helping them grow into whatever the next big revolution is going to be.

We have some ideas and thoughts about what that might be. But we want to prepare the people that come after us to be able to take on the challenges that they face, and the challenges that we face and help them learn from that. One of the things that I very much enjoy is trying to develop that next generation of engineers, commissioning people and all

the people involved with maintaining the utility industry to make sure that we are well suited for whatever the next big change is going to be.

AR Jon that is excellent! This has been an inside perspective from someone who has done it; experience from someone who has even made some of the mistakes that all of us make, and grown from that. As the editor in chief of Transformer Technology, I appreciate the knowledge and insight that you bring us. Thank you for sharing it with us.

JT As always, it has been really nice talking to you, Alan, and I appreciate it. Thank you very much for your time.

One of the things that I very much enjoy is trying to develop the next generation of engineers, commissioning people and all the people involved with maintaining the utility industry to make sure that we are well suited for whatever the next big change is going to be.

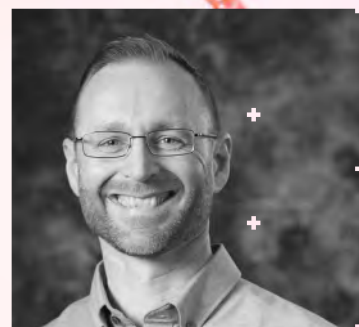
Photo courtesy of Delta Star Inc.



5 Questions on Transformer Grounding

by **Howard Eaton**

+++++



As a veteran of the U.S. Navy and a graduate of the Naval Academy, it's not a surprise that **Howard Eaton** is a big proponent of the Southwest Electric core value Take Action. Howard's day-to-day activities include overseeing the custom switchgear manufacturing plant, as well as many of the substation and switchgear field services. He also maintains the engineering services licensure in several of the states the company serves.

Editor's Note:

Years ago, I worked for a CEO who was one of the most gracious people I had ever known. It was said of him that there were only two reasons that people could get terminated from the company. One was abusive behavior to other employees, whether physical or verbal and the other was – improper grounding. Seriously! It was that big of a thing to him because it was all about safety.

“Work Safe, Home Safe” was the motto of my former company. One of the most important aspects of this motto was to make it something that was deeply rooted in our field crews. These were the employees most at risk from improper grounding of transformers they were going to be working on, and if our crews did not ground properly in their work, then other people and a lot more assets would be at risk. How did we make sure that the proper grounding procedures were followed? We made it a big deal when we communicated the importance that our CEO placed on the proper grounding of transformers; and we trained, retrained and practiced.

This short but very important article answers five critical questions about transformer grounding. We have added this to the Body of Knowledge on our website and I would suggest that if you have any employees or peers who should know the answers to these questions that you forward this article to them. It could save lives. Enjoy, and apply.



● We often focus on the importance of regularly testing and maintaining distribution transformers to preserve and extend their useful life. However, the life and safety of your electrical distribution system begins at installation.

You hired someone to install and ground your transformer. You assumed they understood and followed all appropriate codes and considered the health and safety of your personnel and equipment. But what happens when they do not? Are you aware of some of the dangers that could be lurking due to an error or omission from the contractor? Our crews recently responded to an unfortunate example of just this scenario, involving transformer grounding.

We often focus on the importance of regularly testing and maintaining distribution transformers to preserve and extend their useful life. However, the life and safety of your electrical distribution system begins at installation. One of the critical elements of establishing a safe and effective distribution system consists of proper transformer grounding and connection of the system neutral in 4-wire systems. Those familiar with the National Electrical Code, NFPA 70, will recognize that there is significant time devoted to proper grounds within the code. Many do not understand why, nor the significance of these requirements.

1. What is the purpose of grounding the transformer?

Neutral transformer grounding serves as a permanent and continuous conductive path to "earth" with sufficient ampacity to carry any fault current and sufficiently low impedance to limit the voltage rise above ground, and facilitates the operation of the protective devices in the circuit. These functions reduce shock hazards to personnel and limit damage to equipment. Failing to properly connect and ground the system neutral in 4-wire systems establishes what is often called a "floating neutral". In this condition, the neutral is not referenced to ground allowing voltages to "float" to a maximum of phase RMS voltage relative to ground. The amount of float depends largely on the load balancing of the connected system and can be particularly damaging to single-phase loads. More importantly, this condition creates an extremely dangerous touch potential hazard with the ability to injure or even kill.



2. When should I be concerned about proper grounding?

Recently, our service teams responded to a customer concerned about abnormal heating of a newly installed, refurbished transformer. Electrical testing replicated initial factory test results, but oil sampling showed combustible gases, which indicated overheating. Considering this transformer was lightly loaded and weather conditions during the 5-week period it was energized did not include severe heat, this is an unexpected result. It should also be noted that the crew identified significant variations in phase voltages during their initial inspection. Our recommendations included monitoring the transformer during subsequent operation and retesting in 3 months. The primary concern expressed in our report, however, was the connection of the system neutral. The picture shown should be a red flag to anyone concerned with the health and safety of their employees and equipment. It clearly depicts the failure of the contractor to complete the installation necessary to protect personnel and equipment.





3. Is the transformer properly grounded?

Our first and most urgent recommendation to this customer was to ensure the transformer and distribution system were properly connected and grounded prior to re-energization. Article 250 of the NEC Grounding and Bonding was not adequately nor appropriately followed when this transformer was installed. A system bonding jumper was not installed as required to create an effective ground-fault current path. Additionally, the neutral conductors were not connected to the X0 bushing. They were simply left taped off in the enclosure. Combined, these actions defeat any fault protection associated with the system protection and control scheme. Note that the system neutral should not be grounded at locations other than the service entrance, or, in this case, the supply transformer, as per applicable codes. This could place earth in parallel with the system neutral and create corresponding potential variations.

4. What are the dangers?

Why is this such a critical concern? Primarily, this directly affects the safety and well-being of the operational staff, as well as the downstream equipment. Without establishing an effective ground-fault current path, the ground-fault current will not flow to expose the ground-fault to protective devices. This results in failure of the overcurrent protection device to operate correctly to clear the fault condition. In addition, potential builds on equipment enclosures and surfaces and the risk of electrical shock or electrocution becomes a significant and potentially deadly safety hazard which is usually discovered too late, with tragic results.

Failing to connect the "grounding electrode conductors" can also create a situation where secondary voltages are unstable during operation. This was proved during the initial inspection when phase voltages were observed to vary significantly (nearly 20%). Without a proper return path to the source, phase voltages will often vary with respect to load balancing. In addition to potentially damaging single-phase loads, these voltage variations may be the likely source of the overheating indicated by the presence of combustible gasses and potentially dramatically reduce the service life of this transformer.

5. How do I avoid this happening to me?

The best way to protect your people, facility, and infrastructure is to know where to find answers. For further research and future reference, consider the following significant domestic codes and standards:

NFPA 70 – National Electrical Code (NEC)
ANSI C2 – National Electric Safety Code (NESC)
IEEE 142-2007 – IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (The Green Book)

A thorough understanding of these standards is critical to avoiding similar situations and identifying sources of risk to operations and personnel.





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John Ulcar

Co-founder and Director
at Crosslink Technology

CEO at
Crosslink Technology

Interview with **John Ulcar**

and **Edson Fariello**



Edson Fariello

“

Because we are formulators, we understand the chemistry intimately and know how it could be applied to the bushing. This is what makes us unique.



Founded in 1981, Crosslink Technology has been providing a wide range of chemical engineering services and custom-cast electrical solutions, including transformer bushings, for four decades. In a recent Transformer Technology Tech Talk, we talked to the company co-founder and director John Ulcar and the CEO Edson Fariello about Crosslink's path to the road of excellence.

Alan Ross: In this interview I have the pleasure of talking to two of the leaders of Crosslink Technology - CEO Edson Fariello, the leader taking it to the next generation, and John Ulcar, the founder who is still heavily involved in the organization.

John, when was it that you decided you needed to have a different leader to move things forward? Was it difficult to pass the reins on to Edson?

John Ulcar: This was a part of our succession plan. We have a very aggressive growth plan, and I knew that I wasn't going to be around forever. So, for the continuity of the business and for our customers, we wanted to make sure we had a proper succession plan going forward. Once we found assets, the passing of the baton was very easy. Edson is very talented and skillful. He understands the industry, our customers' needs and how we meet them.

Alan Ross: Edson, tell us a little bit about how you first got involved with Crosslink. What did you know at the time?

Edson Fariello: It started a few months before I joined the company. I had little knowledge back then. It was an incredible surprise when I started talking not only to John, but also to the board. John put together a board for the company to look into the future, and here we are, celebrating our 40th anniversary this year.

I have been very blessed in joining such an incredible organization with such incredible people.

AR Edson, is your background organizational or technical?

EF It is both. I have a degree in chemical engineering, but I also went to business school. Before receiving my MBA, I worked in process engineering, quality control and

production. Then the sales bug got me, and I got involved in sales and marketing for quite some time.

AR John, tell us a little bit about the early stages of Crosslink and how it started, why you started it. Why would you start a company instead of getting a steady job somewhere and retiring at 55?

JU I was always a formulator. The first job I had when I graduated from university was as formulator, particularly in urethanes and urethane foams. My business partner at the time, Karl Egenberger, was an electrical engineer. He noticed there was a great demand for customization for various products. The large players in the market would provide standard products like product cards, but there was very little innovation at the time with the existing suppliers.

We founded a company in 1981, starting as formulators for the electrical and electronic industry and for large companies like Westinghouse, General Electric and Ferranti-Packard. After about two years, we were successful at casting their transformers, particularly the potential transformers (PTs) and current transformers (CTs). The engineers at that time, particularly at Westinghouse, were asking us to formulate products that they could keep in service for 60+ years. That was an important part of their business model, to provide longevity to the electrical grid. We accelerated testing to provide the required properties, and we did it quite successfully.

One day, we had a meeting at Westinghouse when a mechanical engineer came to us with an idea. He worked in the bushings department, where, due to the company size and red tape, it would take them between six and nine months to produce either a prototype or samples. Since we knew epoxies, he asked us to cast some bushings for them.

In well over 30 years, we have not had a reported leakage in the field.



At that time, we had been supplying materials for bushings, but we had never cast one. In about three weeks, we had a mold, cast the bushings and completed the full thermal cycle testing, -40°C to +140°C. Within three weeks, we took three samples to that mechanical engineer. He was so impressed that he asked for twelve more, which became 100 more, which became 1,000 more.

We were selling material for both PT and CT bushings to several other electrical manufacturers, such as Ferranti-Packard, now Siemens, and we noticed a trend: these companies knew how to do casting, but they had issues with casting bushings. The biggest issue was being able to handle the cantilever load and not have a leak. There is an interface between the epoxy and the conductor. We came up with a very proprietary method of castings bushings and in well over 30 years, we have not had a reported leakage in the field. According to some reports, other bushings manufacturers have 5-10% leakage, so our record is really good.

AR That is interesting. At a company I worked for, every year we would celebrate the birthday of 100-year-old transformers in service. And the last year we did it, we had seven that we tested. That is one

of the things I want to talk about - the idea that Westinghouse came along and said they wanted transformers that would last 60 years or more. Many people in our industry do not realize the difficulty of finding bushings, of working with a company that knows about bushings well enough and that understands that the next generation of bushings is going to change everything.

One of the things that fascinate me the most about Crosslink is your ability to meet a customer. How do you approach the customer to provide that customized solution?

EF One of the first things that John taught me when I started with Crosslink Technology was that sometimes you have a transformer worth half a million dollars waiting somewhere for a couple of bushings. The owners cannot ship it and the transformer cannot, in turn, serve their customers. One of the things that we at Crosslink try to do every day is to be really fast. We deal with very short lead times, much shorter than what you would expect from a cast component manufacturer. We are also vertically integrated. On one side of our plant, we make the liquid epoxy that will be used to cast the bushing in the other part of the plant, which helps a lot.

One of the things that we at Crosslink try to do every day is to be really fast.



AR That means that you innovate both the epoxy end and the bushing manufacturing. I would like to go into innovation on behalf of the original equipment manufacturer (OEM). Does the OEM bring you in at an early stage when they are manufacturing for an investor-owned utility? When do they bring you in?

JU They bring us in at the design stage. Let me go back one step. It is interesting that we can have several customers supplying the same end user, each with different requirements for a certain type of bushings. Every single customer is unique despite the fact that we are all in the same industry. In some cases, it could be that the end properties are similar, but the manufacturing and processing requirements are different. Our customization is to the specific customer, which meets the requirements of the end user.

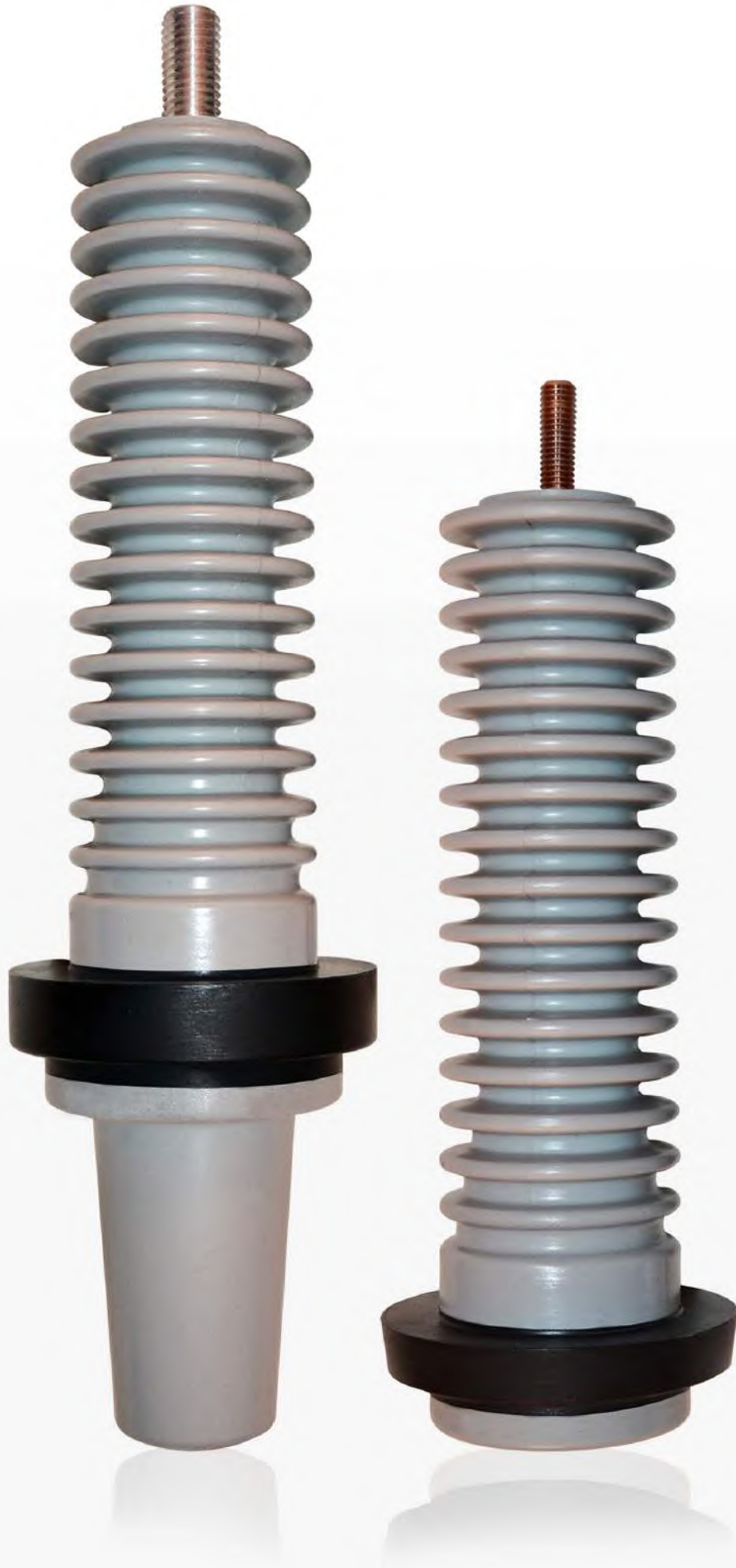


At Crosslink, we have over 1,500 proprietary formulations. Companies not only get us involved in the design of the bushings, but also with the challenges with the supply chain.

AR Where does innovation come when you are meeting somebody else's specifications? Where do you teach that original specifier that they could make a better bushing, safer and longer lasting? Give us a little bit of insight into how you use innovation.

JU There are two components of that process. What I think makes us unique is that because we are formulators, we understand the chemistry intimately and we know how it could be applied to the bushing.

The second part is our electrical engineering. We partner with the electrical engineers of the customer companies, and quite often they are dealing with space constraints. There is partial discharge, and a number of other electrical properties that have to be accounted for. In



some cases, the design can be done by both the customer engineers and our engineers.

And then there is the chemical part of it. In some cases we design the epoxy to meet the processing requirements; in other, there are mechanical requirements. They have a high cantilever requirement because of the cables that are being attached to it, as well as extreme thermal cycling or extreme temperatures. We balance the mechanical properties and the chemical properties of the epoxy with the design itself. That is where I think we marry the two together very neatly.

AR One of the things that we believe is a foundational principle is the principle of excellence. How have you built it in? If you have been in business with a formulating division and a casting division for 40 years, you must have a reputation for excellence.

EF I think it is a daily endeavor, Alan. As John was saying, and I myself have seen,

There are three different things, and that is the reality of the customer market we live in. As the market changes, it is going to impact everyone. Where is Crosslink going to fit that niche, and what you are going to focus on as a company the most?

JU Right now, we are focusing on two new developments within the bushing industry. One is to decrease the partial discharge in the electrical and increase some of the electrical properties within the epoxies themselves.

We have a program in place to start developing products with improved properties that will increase their longevity in the field.

A property we are focusing on the most is decreasing partial discharge. Our goal is to get to zero, that is the brass ring. We are making significant improvements in that part of the business. Secondly, we are looking at mimicking porcelain from the point of view of self-cleaning

Our future efforts are focused on decreasing partial discharge as well as developing a system that will ensure the bushings have self-cleaning properties, approaching those of porcelain.

we not only have companies getting us involved in the design of the bushings, but also with the challenges with the supply chain. We have over 1,500 proprietary formulations. It is very rarely that we have to start from scratch on any resin, particularly the ones that we use for bushings. We are making more investments this year on the technology required to make bushings and to improve our manufacture of the resins. This is an ongoing process that will continue over the next five to ten years. It is the way to go for every company that wants to maintain the speed of delivery and be able to customize the solutions to their customers.

AR The world today is agile. You have to be flexible and be able to adjust. It sounds like that agility is built into your DNA, which is a huge advantage.

Here is a hard question. We have moved into a situation where purchasing always wants the cheapest price, engineering wants the product that meets specifications and works, and a CFO wants the lowest total cost of ownership.

out in the field, especially in polluted areas. As is commonly known, porcelain is not the easiest product to work with. It is brittle, and it has other issues, but it does have great outdoor self-cleaning properties. With epoxy, we are providing a product that is much more stable from a mechanical point of view. Even if some hunters want to shoot at it as practice, it will not be destroyed in the field. At the same time, we are developing a system that will ensure the bushings have self-cleaning properties, approaching those of porcelain.

AR If you get even close, that is a big deal. We know that weather is the biggest enemy of porcelain. If you can solve both of the problems, that would be one of the next-generation innovations that are coming.

I would like to congratulate Crosslink on 40 years of excellence. Thank you for being that kind of a privately held company in this massive industry that is providing value and a lower, total cost of ownership, and passing on the legacy to the next generation.

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SOLVING MOVERS FOR THE TRANSFORMER INDUSTRY

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Solving is one of the leading manufacturers of customised systems for handling heavy loads. Based on over 40 years of experience we provide solutions both on air bearings and wheels.

Air film technology is considered ideal for handling transformers weighing several hundred tons quickly and smoothly through production and test facilities.

Solving provides a variety of transporters for handling transformers, windings, cores and components ranging from simple manual Movers for smaller components to remote controlled and automated systems for bulky windings and transformers and for frequent operation.



Solving Movers for transformers weighing up to 700 tons

Several manufacturers of transformers have used Solving's Air Film Movers a long time to assemble windings, cores and active parts and to move them into vacuum ovens. Air film technology provides all the necessary freedom and flexibility for moving completed transformers weighing up to 700 tons. Electrical drive units and integrated batteries improve the flexibility of the Mover and allow it to be operated without load free of any trailing cables or air hoses; these are connected only when a loaded steel pallet is to be moved. The Movers can be used individually for smaller transformers or as a combination of two or three units controlled from a single radio control console.

Wilson Transformer Company



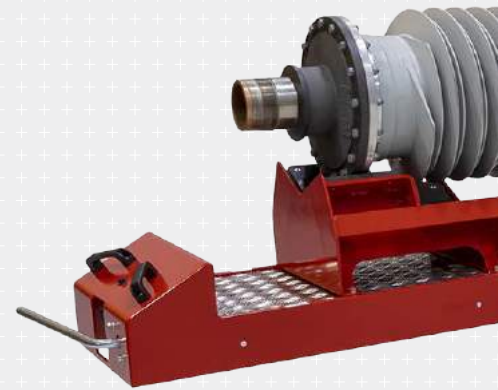
Solving Movers for transformers weighing up to 50 tons

Solving provides handling equipment for cores, windings and components weighing up to 50 tons. The equipment often consists of an Air Film Mover incorporating all the necessary technology, designed to lift and accurately move steel pallets from one station to another. An Air Film Mover consists of a rigid steel construction incorporating both air bearings and wheels, drive units, a control system and in some cases also a hose reel for the air supply. Usually, one single operator maneuvers the system from a portable radio transmitter.



AN EXAMPLE OF AN AIR FILM BASED MOVER HANDLING TRANSFORMERS WEIGHING SEVERAL HUNDRED TONS

High voltage power transformers are amongst the largest and heaviest production items found anywhere in the world. Apart from the extreme size and weight of these giants, testing requires very high voltages to be applied, requiring safe clearances between the connections and the surrounding building structure. When these connections, high voltage bushings, are assembled and cooling oil is added immediately prior to test the transformers become too large and heavy for most cranes. This used to mean carrying out final assembly in the test area, but power transformers can now be moved after final assembly without cranes using Solving's latest sophisticated air-film based Mover system.



AN EXAMPLE OF AN AIR FILM BASED MOVER HANDLING TRANSFORMERS WEIGHING SEVERAL HUNDRED TONS

EQUIPMENT

The equipment consists of two 230-ton radio-controlled Movers together with an 80-ton auxiliary beam. These can be used individually for smaller transformers or combined as a 540-ton system, controlled from a single radio-control console.

CONSTRUCTION

Transformers are assembled on steel pallets which allow the Movers to pass underneath in preparation for a move. An on-board battery system and electric drives are used to control the movement of the unloaded system and each Mover contains an integral hose reel for connection when a heavy lift is to take place. Once the air bearings have been activated the transformer can be driven in any direction, rotated and turned as required.

RESULT

Customers have found that the flexibility provided by the Solving system provides them with maximum efficiency in test departments and enables all assembly processes to take place in the production areas.



SOLVING WHEELED MOVERS

There are various kinds of Solving wheeled Movers, all of them being tailored to suit specific customer requirements. One example is a wheeled Solving Mover for smooth handling of transformer bushings in a narrow layout.

Solving has installed a customised, radio-guided and battery-powered Mover to move transformer bushings in a production area. The Mover frame is telescopic and thus adjustable to loads of various lengths. Due to a very narrow layout, the Mover must be able to drive omnidirectionally: forwards, backwards, crossways and diagonally. The Mover is controlled with a portable remote-control unit, allowing the operator to supervise and drive both the Mover and load in a safe way. Additional safety is provided by collision sensors, which warn the operator whenever an object is detected in front of the Mover.

SOLVING IN BRIEF

Solving is one of the world's leading manufacturers of industrial handling equipment for heavy loads. Our products range from simple, manually operated systems to automated riderless vehicles for continuous operation.

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Temperature Rise Test Corrections for Three-Winding Transformers with Axial Split-Windings

by **Jason Varnell**

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Photo: Shutterstock



Jason Varnell is a member of Doble Global Power Services, employed as a Principal Transformer Engineer working on projects that include factory inspections, condition assessment, design reviews, failure analysis and other general consulting projects. He has over 10 years of experience, having most recently served as Lead Design Engineer at SPX Transformer Solutions in Goldsboro, NC where he managed an electrical design group. He has extensive expertise in core-form transformer design and construction having personally designed several hundred power transformers. An active member of IEEE Transformer Committee, Jason has contributed to the revision or creation of a significant number of IEEE transformer standards. Jason Varnell received a bachelor's degree in Electrical Engineering (Honors) from the North Carolina State University with an emphasis in Power Systems and Power System Protection.

Introduction

In core-form transformers with a concentric winding arrangement, two or more separate winding sections may be situated one above the other (axially). This unique arrangement is commonly referred to as "axial split-windings" or "axially-stacked windings". The split-winding arrangement is most commonly used in three-winding rectifier transformers and three-winding unit auxiliary transformers (UAT). Three-winding transformers with axial split-windings are unique because the two axial sections are normally associated with two different terminals. Therefore, unique combinations of varying voltage, impedance and active power can be present, which requires special consideration.

In addition to the various possible terminal characteristics described above; there exists a fundamental difference in the temperature rise distribution model when compared to the traditional full-axial height winding arrangement because the relative top-oil, average-oil and bottom-oil temperature rises are not the same for all windings. It is therefore necessary to understand the differences in the two temperature rise distribution models and then be able to refine the relative oil temperature rises for each winding in order to appropriately determine the average winding temperature rise and winding hottest-spot temperature rise for each winding.

Presently, industry standards do not explain the modifications that are needed to the temperature rise test for these special winding arrangements. This paper will demonstrate how to supplement the industry standards for this unique transformer construction and some common problems that arise in practice.

An application for the axial split-winding arrangement may be to serve large unit auxiliary loads within one three-winding transformer at a generation plant, as opposed to using two separate two-winding transformers.

Winding Arrangement

The traditional and most common winding arrangement for core-form transformers includes an arrangement in which the windings are approximately the same height and are arranged concentrically over one another (radially). Figure 1 depicts the traditional transformer winding arrangement for a three-winding transformer with the primary (designated as "HV") placed concentrically in-between two secondary windings, "XV" and "YV". The axial split-winding arrangement includes two or more separate winding sections that are situated one above the other axially. An application for the axial split-winding arrangement may be to serve large unit auxiliary loads within one three-winding transformer at a generation plant, as opposed to using two separate two-winding transformers. The application could allow interconnection of two separate auxiliary buses and possibly with secondary voltages and active power ratings at different levels [1]. Figure 2 depicts an axial split-winding arrangement with one set of secondary windings designated as "YV" placed axially above the other set of secondary "XV" windings.

The importance in noting the difference between the axial split-winding arrangement and the traditional concentric winding arrangement is that the transformer temperature rise distribution is

appreciably different between the two arrangements, and therefore greater attention is required in determining the oil temperatures. Namely, in the axial split-winding arrangement, the "YV" winding from Figure 2 should not use the average-oil temperature rise of the tank oil, rather it is necessary to determine the average-oil temperature rise for the "YV" winding separately from the tank average-oil rise.

Transformer Temperature Rise Distribution

In the traditional transformer temperature rise distribution model, the winding heights are assumed to be uniformly distributed within the transformer core window.

This assumption yields additional assumptions such as the top-oil temperature rise is adjacent to the top of the windings and, similarly, the bottom-oil temperature rise is adjacent to the bottom of the windings. In other words, the temperature rise of the oil inside the windings is assumed to increase linearly with the height of the windings. Additionally, the heat generated from the windings, in the form of losses, is assumed to transfer (on average) to the adjacent oil in proportion to the corresponding winding height. In graphical form, these assumptions result in two parallel lines, with one representing the winding temperature rise relative to height and the other representing the oil temperature rise relative to



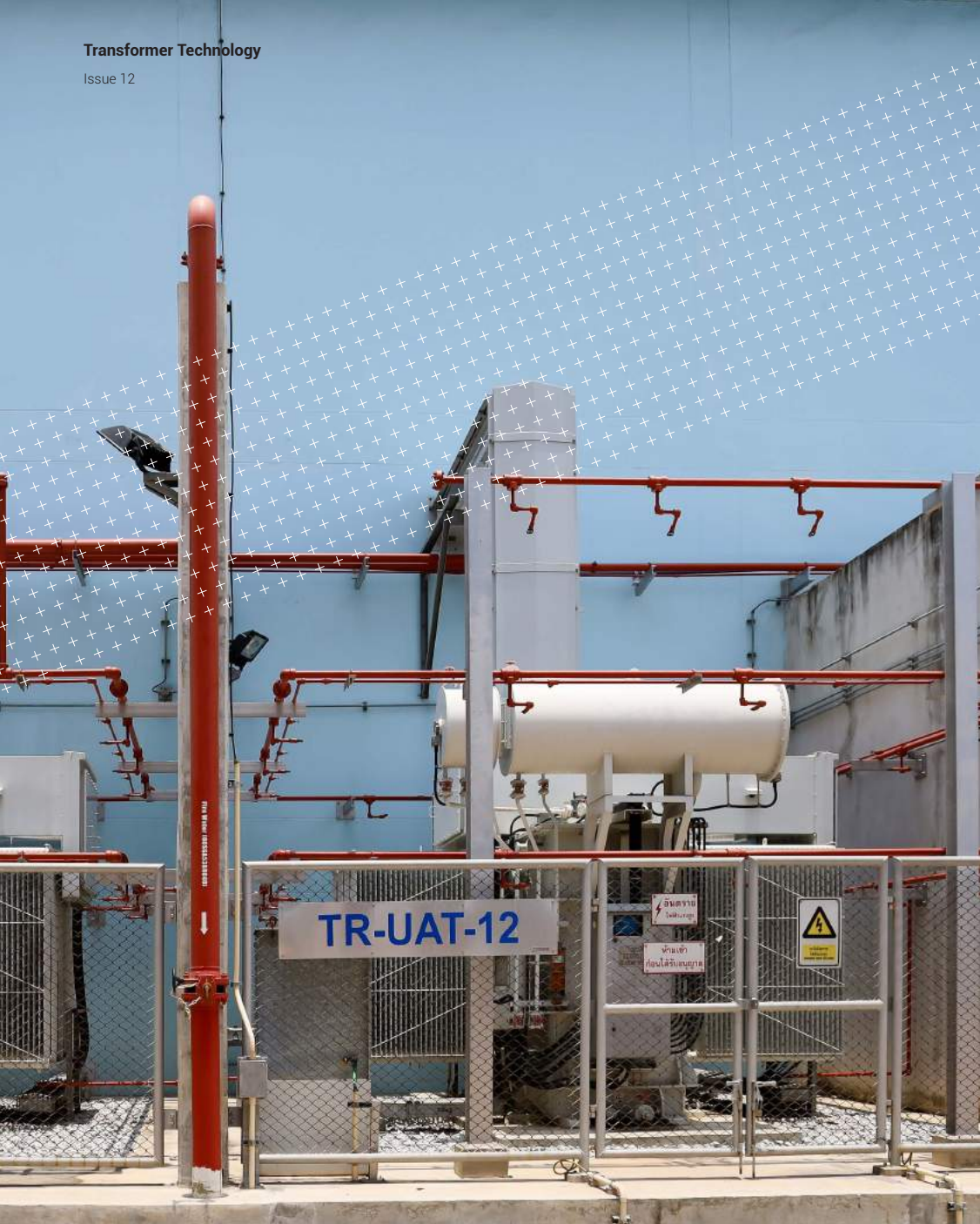


Figure 1. Traditional transformer winding arrangement

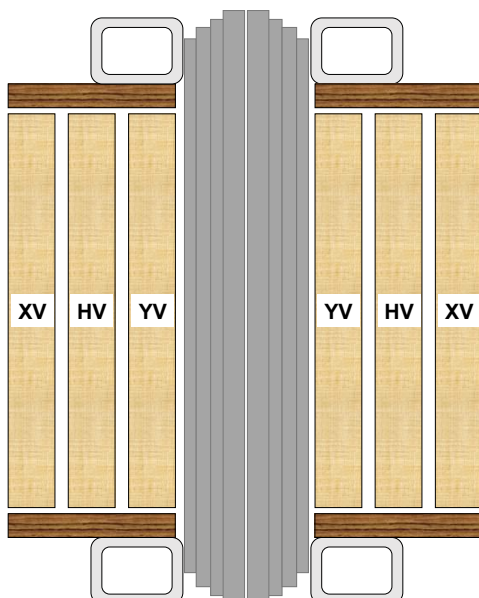
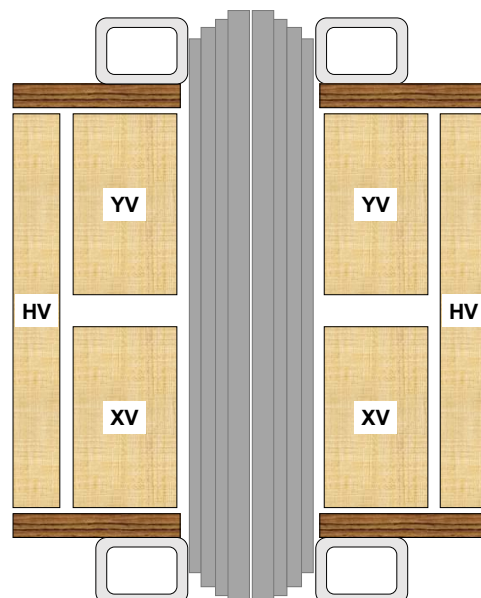


Figure 2. Axial split-winding transformer winding arrangement

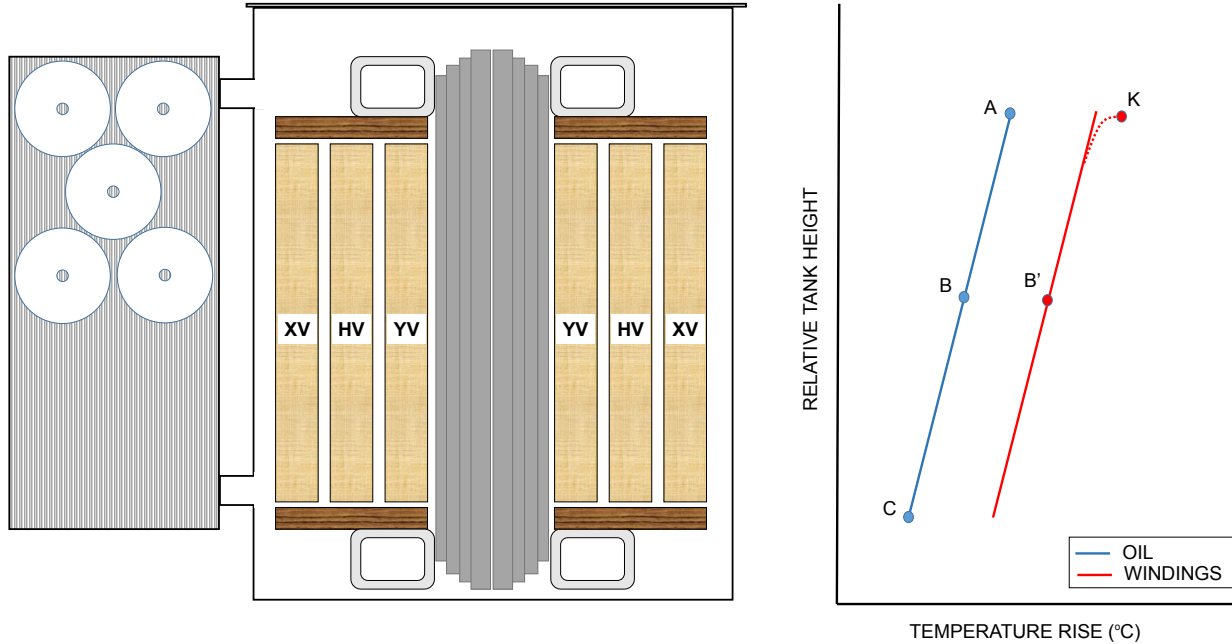


height. The difference between the two parallel lines is the temperature drop between the winding and the adjacent oil, which is commonly referred to as the average winding gradient.

In the traditional transformer temperature rise distribution model, the average-oil temperature rise (Figure 3 – Point B) is determined by the arithmetic mean of the top-oil temperature rise (Figure 3 – Point A) and bottom-oil temperature rise (Figure 3 – Point C). Also, in the traditional model, the average winding temperature rise (Figure 3 – Point B') is the sum of the average-oil temperature rise and the average winding gradient. Point K in Figure 3 is the winding hottest-spot ("hotspot") temperature rise and is determined by the sum of the top-oil temperature rise and hotspot gradient, which is determined by a hotspot factor and the average winding gradient. The hotspot factor is a dimensionless quantity greater than 1.0 and is individually assigned to each winding based on a combination of mathematical analysis and empirical test results from direct measurement [2].

A figure similar to Figure 3 can be found in International Standard IEC 60076-2[3]. The IEC standard uses similar

Figure 3. Traditional transformer temperature rise distribution model



points to help illustrate the terms for bottom-oil, average-oil, and top-oil temperature rise; however, it defines the vertical axis of the chart as "Winding Height (%)." Although the IEC standard associates the 0%, 50%, and 100% of the winding height with the location of the bottom-oil temperature rise, average-oil temperature rise, and top-oil temperature rise of the tank (respectively); the differentiation in the vertical axis is useful for the axial split-winding transformer temperature

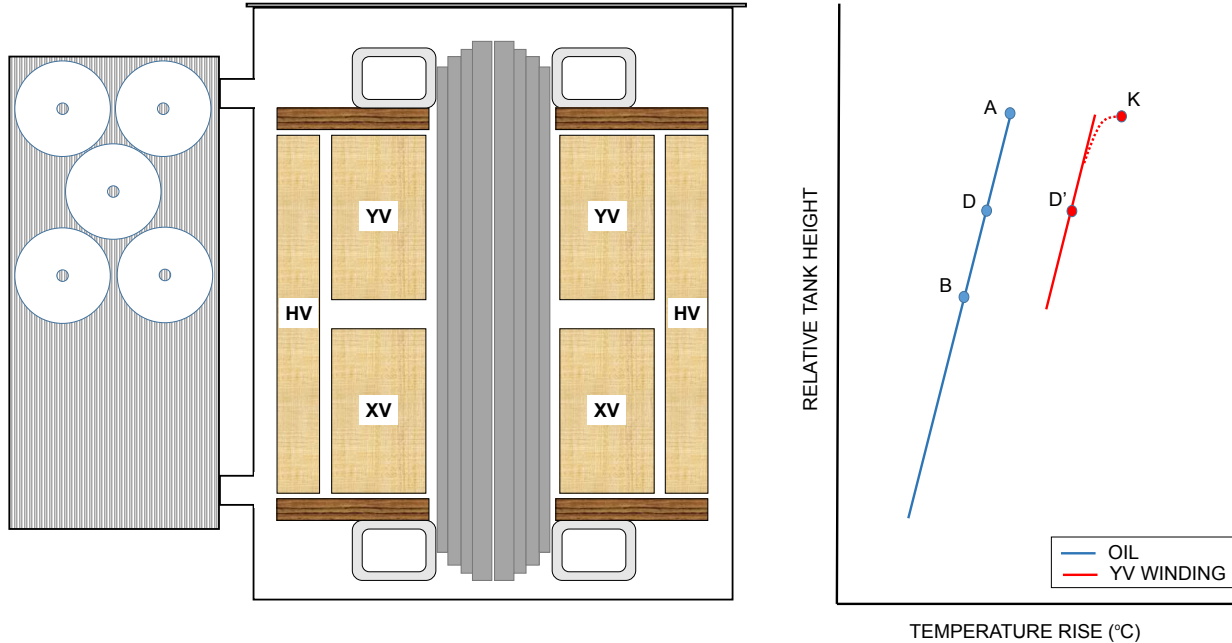
rise distribution model. In the axial split-winding transformer temperature rise distribution model, one of the main differences is the oil temperature rise to be used to determine the average winding rise. It should not use the average-oil temperature rise (Figure 4 – Point B) of the tank oil, rather it is required to determine the average-oil temperature rise across the "YV" winding, which is Point D in Figure 4. Point D is the arithmetic mean of the oil rises from points A and B of Figure 4.

The "XV" winding in Figure 4 will require similar adjustments to the temperature rise distribution model. The "HV" winding in Figure 4 uses the traditional temperature rise distribution model because the windings are not stacked axially and are full height.

Corrections to the Temperature Rise Test

The purpose of the temperature rise test is to establish the top-oil

Figure 4. Axial split-winding temperature rise distribution model for YV winding



temperature rise, average winding temperature rises, and winding hottest-spot temperature rises. The temperature rise test is primarily composed of four components. The first component is the cold-resistance measurements of the windings. Next is the total loss injection for determination of oil temperature rise. Special attention is given to each component of the temperature rise test for transformers with axial split-windings, but this paper will focus on the cold-resistance measurements and total loss injection because the principles described can easily be applied to the other two remaining components.

Cold-Resistance Measurements

The industry standards have very definite criteria to minimize recording errors in the cold-resistance measurement [4]. One of the major prerequisites is the determination of the cold winding temperature since resistance varies proportionately with temperature. Cold resistance measurements require the windings and oil temperature to be stable. This stable reference temperature for each axial split-winding should follow the method for determining the oil temperature rises according to the axial split-winding temperature rise distribution model.

Total-Loss Injection

The most common method for temperature rise testing power transformers is to utilize the short-circuit method, whereby the load is simulated by the effect of short-circuit current. In the case of total-loss injection, the primary goal is to simulate and sustain total-losses on the transformer that coincide with previously measured no-load and load losses for a given active power rating for the purpose of determining the steady-state oil temperature rises.

One difficulty that can occur during the total-loss injection for three-winding transformers, which may also be prevalent during the rated winding-current injection portion of the temperature rise test, is that differences in impedances and active power ratings can result in under-loading or over-loading of certain terminals under test. Figure 5 helps illustrate the equivalent three-winding impedance network and can be derived from Equations 1 through 3. Equation 4 and Equation 5 can be used to solve for the load-current division if both the "XV" and "YV" terminals were shorted during the short-circuit method of the temperature rise test (i.e. a short across point "X" and point "Y" in Figure 5).

This stable reference temperature for each axial split-winding should follow the method for determining the oil temperature rises according to the axial split-winding temperature rise distribution model.

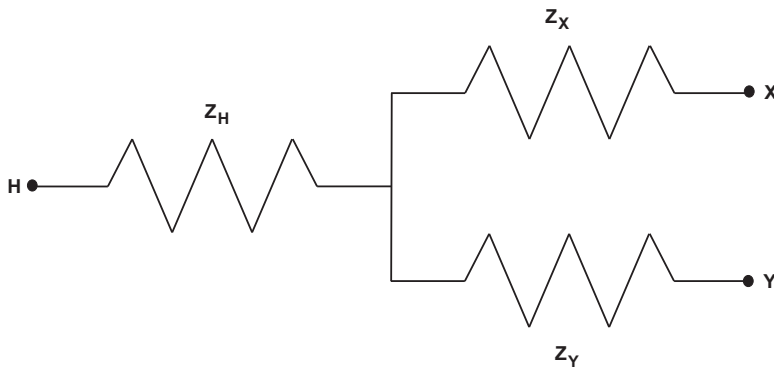
This can present difficulties in achieving total-loss injection because the over-loading of one set of terminals may be significant and result in exceeding recommended temperature rise limits or current ratings of ancillary equipment. Therefore, it is recommended that the details of the temperature rise test for transformers that fall within this scenario be presented and agreed to during the tender stage. The transformer manufacturer may present recommendations to inject less than 100% of the total-losses and then apply corrections to the oil temperature rises as outlined in the industry standards [3], [4]. It should be noted that the industry standards typically have a minimum percentage

of the total-losses for which the temperature correction equations are valid. Due to the transformer impedance requirements or active power ratings, it is possible that the required total-losses fall outside of the minimum percentage as indicated in the industry standard. Alternatively, it may be of interest to the end user to meet and not deviate from the industry standards. Therefore, it may be recommended to have the transformer manufacturer design the transformer windings and ancillary equipment to withstand any resulting over-loads, which result from maintaining at least the minimum percentage of the total-losses as indicated in the industry standards. It should be noted that the industry standards also have upper ranges for the percentage of total-losses and rated winding current for which oil temperature rise correction calculations can be made; however, the IEEE and IEC standards are not in agreement in regard to the allowable ranges.

There are additional considerations that may need to be considered in determining the required total-loss for unique three-winding transformers such as axial split-winding transformers. The derivation of the load-current division from Equation 4 and Equation 5 and the use of the measured impedances and losses for each two-winding combination can result in some inaccuracies in large transformers where eddy losses in windings and stray flux losses in structural components are considerable. Additional corrections to determine the three-winding (combined) total-losses may be useful and required [5].

After the top-oil temperature rise has stabilized during the total-loss injection, according to the requirements in industry standards, then the short-circuit current should be reduced to the rated winding currents. The instant where the total-loss injection transitions to the rated winding-current injection is commonly referred to as "cutback." The oil temperatures should be recorded for the total-loss injection

Figure 5. Equivalent three-winding impedance network



immediately before the cutback. The recorded oil temperatures should be categorized according to the axial split-winding temperature rise distribution model for windings that are axially-stacked. These categorized oil temperature rises, from the moment of cutback, will be used to determine the final average winding temperature rises and winding hottest-spot temperature rises after rated winding-current injection and hot-resistance measurements are completed.

Other Special Thermal Considerations

The axial split-winding example presented in this paper illustrated two axially-stacked sections divided into two equal height winding segments. In practice, other winding constructions are possible, such as two unequal height winding segments due to differences in voltage or impedance requirements. Unequal height winding segments present additional challenges in determining the bottom-oil, average-oil, and top-oil temperature rises for each axially-stacked winding.

It may also be advisable to install temporary or permanent temperature measurement probes at the winding heights that coincide with the tank oil adjacent to the bottom, middle, and/or top of the axial split-windings. Additionally, a different temperature rise calculation method can be applied based on the proposed winding heights of each axial split-winding.

If direct measurement is used to determine the winding hottest-spot temperature rise during the temperature rise test, and there exists unequal loading of the axial split-windings, then the direct measurement may not result in

Due to the transformer impedance requirements or active power ratings, it is possible that the required total-losses fall outside of the minimum percentage as indicated in the industry standard.

meaningful winding hottest-spot temperature rises at rated load for all of the windings. It should be noted that this scenario exists due to the short-circuit temperature rise test method; however, it is not a limitation that necessarily exists in operation. For reasons already explained in this paper, it is possible that one of the axial split-windings will be under-loaded while the other over-loaded during temperature rise testing, which means that a more refined calculation may be necessary to determine the calculated winding hottest-spot temperature rise from the direct temperature measurements.

$$Z_H = \frac{Z_{HX} - Z_{XY} + Z_{HY}}{2} \quad \text{Equation 1}$$

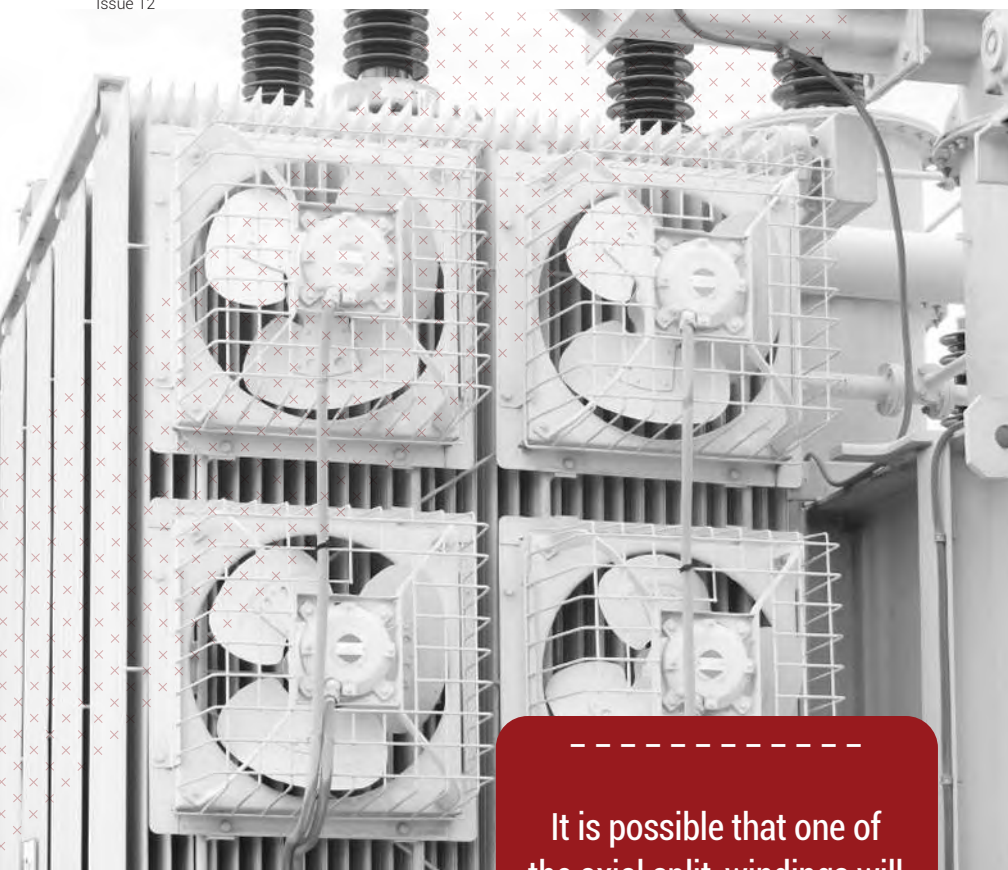
$$Z_X = \frac{Z_{XY} - Z_{HY} + Z_{HX}}{2} \quad \text{Equation 2}$$

$$Z_Y = \frac{Z_{HY} - Z_{HX} + Z_{XY}}{2} \quad \text{Equation 3}$$

$$MVA_X = MVA_H \frac{Z_Y}{Z_X + Z_Y} \quad \text{Equation 4}$$

$$MVA_Y = MVA_H \frac{Z_X}{Z_X + Z_Y} \quad \text{Equation 5}$$





It is possible that one of the axial split-windings will be under-loaded while the other over-loaded during temperature rise testing.



Due to the difficulty in obtaining a correct measurement at full load and total-losses, it may not be advisable to use the direct measurement to guarantee the winding hottest-spot temperature rise. Another option may be to determine the hotspot factor from the direct temperature measurement [2] for each axial split-winding at the presumed loading based on the load-current division as determined from Equation 4 and Equation 5. Once the hotspot factor is determined for the applied test current then the temperature corrections based on the industry standards can be applied to the oil temperature rises and winding temperature rises. The hotspot factor can then be applied to the corrected winding gradient and then added to the top-oil temperature rise for each axial split-winding. When determining the hotspot factor, it may be necessary to review the variation in the hotspot factor at different percentages of rated load [6].

Conclusion

Transformers with split axial-windings present unique challenges when performing temperature rise testing. The industry standards generally have enough provisions to determine the oil and winding temperature rises for split axial-windings if some discretion is used in applying various corrections as presented in this paper. This paper provided some considerations for the temperature rise distribution model and temperature rise test via the short-circuit method. This paper emphasizes the necessity to consider transformers with axial split-windings as a unique design, which requires special involvement between the buyer and transformer manufacturer during the tender stage.

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GFRP

INSULATION COMPONENTS ALLOW REVISIONS TO TRANSFORMER DESIGN

How Durostone® CR contributes to compact design and resilient transformers

One of the megatrends is urbanization: Urban living is the dominant lifestyle of the future. By 2050, two thirds of the world population will live in cities. This leads to an increasing demand for energy in the same space. Therefore, transformers with the same or smaller dimensions, but with higher capacity, are needed. Additionally, the need for mobile transformers is increasing while aged transformers are replaced.

Both developments require transformers to be compact and more resilient. This leads to higher requirements for the construction insulation materials in the active part of the transformer. The new Durostone® CR materials' mechanical properties provide the ability to revisit the overall design.



Shield end ring made of Durostone® CR:
Close tolerances because of no shrinkage leading
to high dimensional stability

Glass fiber reinforced plastic (GFRP) is a material that has so far only played a subordinate role in the construction of oil-filled transformers, but it has the potential to boost the construction of compact and high-performance designs.

The current construction elements inside the transformer are steel and wood-based materials like laminated press-board (LP) and laminated densified wood (LDW). But a material that has so far only played a subordinate role in the construction of oil-filled transformers has the potential to boost the construction of compact and high-performance designs: glass fiber reinforced plastic (GFRP).

Compared to steel, the electrical properties of GFRP provide advantages in terms of stray losses and smaller transformer design.

Compared to wood-based materials, GFRP provides better mechanical properties. In addition, the operating temperature of GFRP is higher, since wood-based materials are normally used at a maximum operating temperature of 105°C. On the contrary, the critical property for fiber-reinforced plastics are the electrical properties in point of partial discharge. GFRP does not absorb any oil. Therefore, the manufacturer must ensure that the material is free of air bubbles. A special know-how is required in the production process and special resin systems to fully utilize the advantages of GFRP.

Durostone® CR was specifically developed for oil-filled power transformers with the highest requirements.



Platform made of Durostone® CR:
improved mechanical properties and reduced
clamping ring thickness

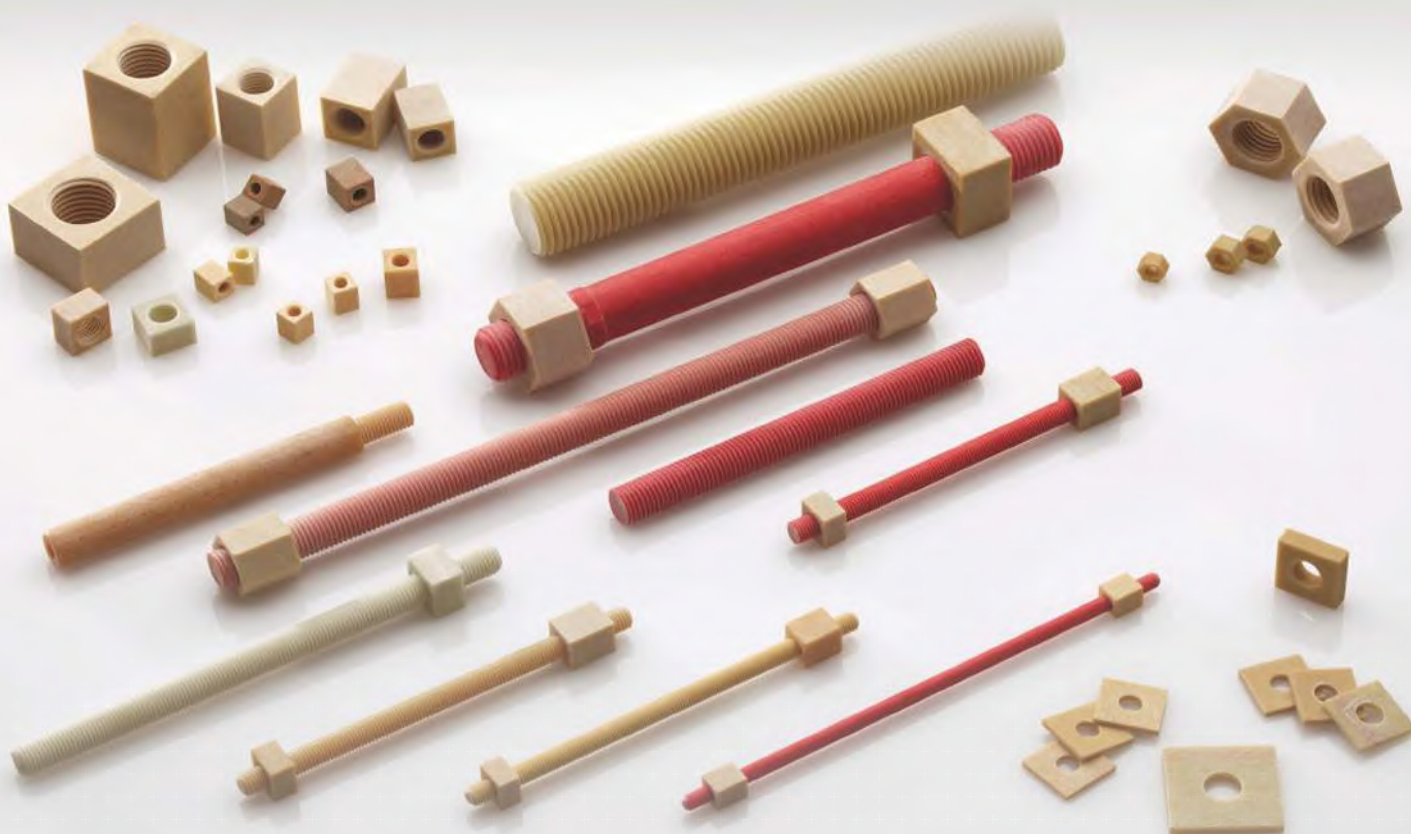
Durostone® CR provides higher performance, more compact design with a higher capacity and higher operating temperatures, thus supporting a new design for modern transformers performing at the highest requirements.

Röchling Industrial, a world-leading plastics and composites manufacturer, has more than 60 years of experience in the production of high-power insulating materials. Röchling has been challenged to develop GFRP grades for transformer construction. The new materials are combined in the Durostone® CR (CR = Compact & Resilient) product family. Durostone® CR was specifically developed for oil-filled power transformers with the highest requirements.

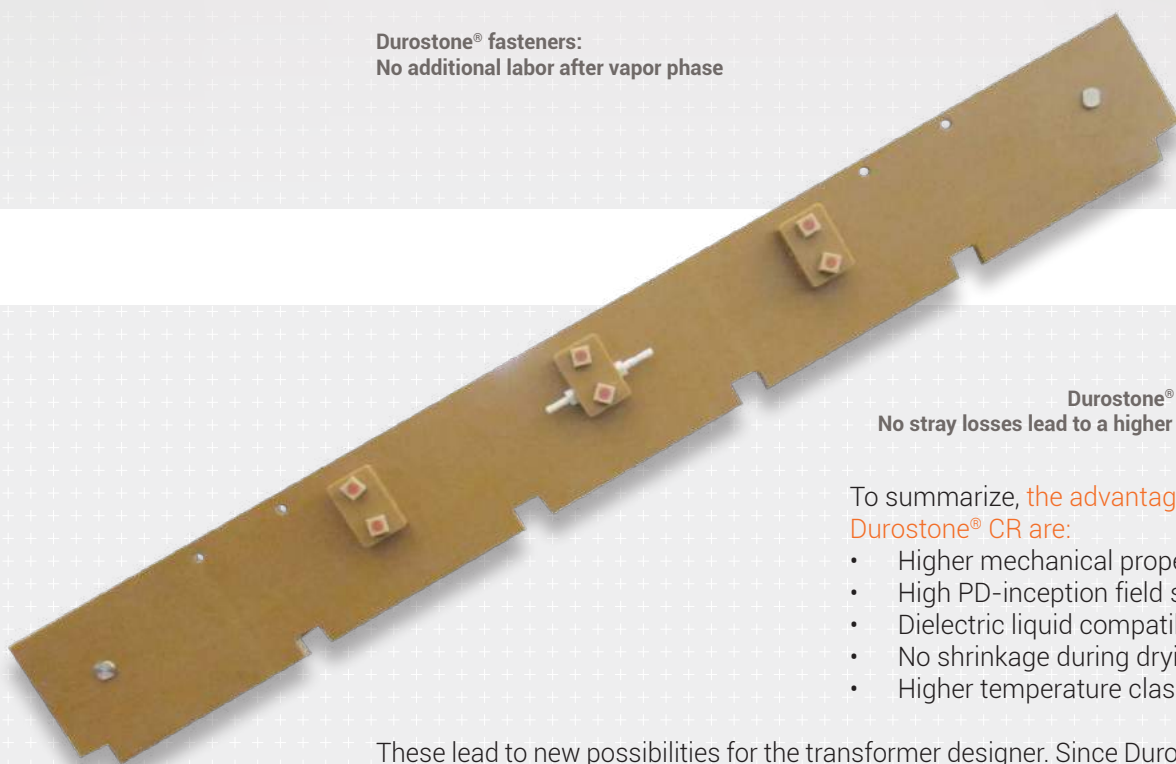
The difference to common composites is the high dielectric strength without onset of partial discharge, which is much lower for typical fiber-reinforced plastic compared to laminated pressboard (LP) and laminated densified wood (LDW). With Durostone® CR dielectrical properties of up to 10 kV/mm without onset of partial discharge are possible, which is on the same level with LP. Highest reliability for the electrical insulation properties is crucial for the construction elements in the active part of the transformer.

For the development of Durostone® CR, Röchling made use of the broad experience with LDW and LP. The Röchling brand Lignostone® Transformerwood® has been used in transformers for over 60 years. In 2009 Röchling expanded with Trafoboard® HD-PH, a laminated pressboard with excellent dielectrical properties.

The electrical properties of Durostone® CR in point of onset of partial discharge are approved from well-known institutes in the industry which have the highest standard with a measuring sensitivity for partial discharge of <1 pC. The compatibility with dielectric liquid has been tested by Doble with no negative influence. Furthermore, Durostone® CR has the advantage of no shrinkage during the drying process because it is not hygroscopic. This provides closer tolerances and a more stable design. Additionally, it can be advantageous for threaded rods since there is no need for reassembling after the drying process.



Durostone® fasteners:
No additional labor after vapor phase



Durostone® CR beam:
No stray losses lead to a higher efficiency

To summarize, the advantages of Durostone® CR are:

- Higher mechanical properties
- High PD-inception field strength
- Dielectric liquid compatibility
- No shrinkage during drying
- Higher temperature class

These lead to new possibilities for the transformer designer. Since Durostone® CR is available in large dimensions, it can be used as a clamping ring with a diameter of up to three meters, for very high mechanical requirements. Beams and fasteners with a length of more than 5 meters are available. It can replace steel beams due to its very high stiffness of up to 30 GPa, which reduce eddy currents in the beam and gives more freedom in the HV-Design.

All these factors support a new design for modern transformers performing at the highest requirements. Durostone® CR provides higher performance, more compact design with a higher capacity and higher operating temperatures.

Transformer Insulation (Quality) Matters

by **Mark Suddarth**

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Today's electric utilities are driven by customers' needs and have a very low tolerance for failures, making "risk-costs" a very real consideration. The quality of the insulation system used inside a transformer is critical to the requirements that matter most to the asset owner: reliability, efficiency, and longevity.



Mark Suddarth has more than 30 years of experience in Business-to-Business industrial sales and product management at a global level, with the last 12 years at Weidmann Electrical Technology. He has an MBA from Webster University and a BS in Biomedical Engineering from Vanderbilt University. Mark has extensive knowledge of crepe and flat/kraft insulating materials, with responsibility for expanding Weidmann's customer base and developing the overall Americas region business strategy for all crepe materials. In addition to Mark's passion for engineering and all things paper, he is also quite the linguist with fluency in English and French along with knowledge of Spanish and Arabic.

Since each transformer can feed a large number of customers, failure of a single transformer and the resulting loss of service means lost revenue, repair or replacement, and other collateral costs to the asset owner and operator. Sudden, catastrophic failures can be highly visible and negatively impact customer satisfaction and

bottom-line financial performance of the utility/asset owner.

When utility engineers and managers were asked in a recent survey to rank the importance of operation factors, they listed equipment reliability as the number one for the following reasons:

- Reduce unplanned outages
- Minimize the risk of major

incidents, especially with an aging fleet of transformers

- Reduce maintenance cost and cost of the overall operation
- Reduce insurance costs

In normal power transformer operation, the condition of the insulation system determines the life expectancy of the transformer.

A simple risk analysis shows the different levels of risk for the transformer manufacturer and the owner/end user relating to insulation.

Many do not recognize the importance of specifying the insulation system and the vital role it plays in the attainment of the specification's objective.



	Transformer manufacturer	Transformer owner / End user
Insulation cost	2-8% of transformer selling price	Negligible percentage of cost of substation or generating plant where the transformer is located
Risk	Test floor or in-service failure within warranty	In service failure and resulting cost
Capital at risk	Cost of rework or replacement	Partial or total loss of substation or generation plant 7-10 times transformer cost
Duration at risk	Transformer production and warranty period (1-5 years)	Transformer operational life 20-30 years

Specifying high quality insulation materials will only negligibly impact the overall price, but significantly augment the efficiency, reliability, and longevity of the asset, lowering the end user's total cost of ownership.

Simply stated, while important to both the manufacturer and end user, the risk for the end user is much greater than that of the transformer manufacturer. Since the quality of materials used inside a transformer is critical to the requirements that matter most to the asset owner – reliability, efficiency and longevity, it stands to reason that the purchaser should have a greater say in the selection and design of the insulation system.

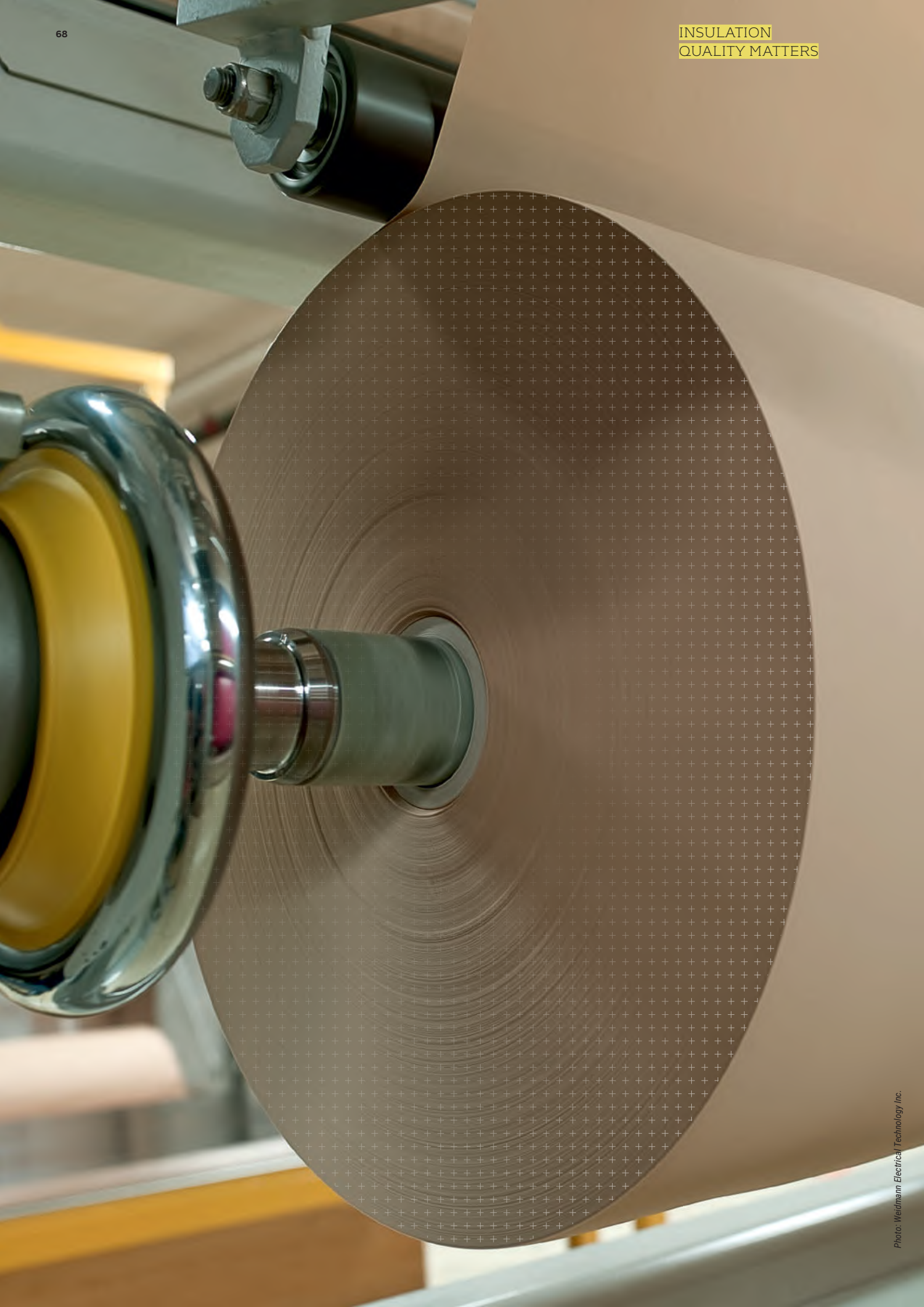
Have you ever wondered why there can be a significant difference in prices offered by different manufacturers for the same quote request? How is this possible? A major reason has to do with the priorities and strategy of the transformer manufacturer. The first priority is for the unit to pass the factory test so it can be shipped and sold. The second priority is to get the transformer through the warranty period, so they are no longer responsible. These priorities sometimes lead the manufacturer to use cheaper, lower quality insulation alternatives, but these types of materials will not deliver the long term reliability needs of the end users who rely on the transformer to operate efficiently and reliably for many years.

Many transformer purchasers' specifications contain very specific requirements for items such as copper conductors, core materials, fluids, cooling equipment, bushings gauges, instruments, paint and external components/hardware. However, many do not recognize the importance of specifying the insulation system and the vital role it plays in the attainment of the specification's objective. Given that the total insulation system cost makes up only 2-8% of the total transformer price, you would anticipate that all operators/end users would specify this in their tender documents, but this is not the case. Specifying only the highest quality insulation materials available to be used inside the transformer will negligibly impact the price whereas significantly augment the efficiency, reliability, and longevity of the asset and lower the end users, total cost of ownership.

In the final analysis, it is the responsibility of the utility transformer specialist to specify the best transformer designs and materials for construction to maximize operational reliability, while minimizing risk, as a key part of their investment and



The condition
of the insulation
system determines
the life expectancy
of the transformer.



The quality of materials used inside a transformer is critical to the requirements that matter most to the asset owner: reliability, efficiency, and longevity.

performance improvement strategies. With the insulation system of the power transformer making up only 5% of the total cost and a fraction of the total investment of a generation facility or substation, it makes sense to specify the best insulation materials, designs, and systems to reduce overall risks and total cost of ownership.

Another important reason end users should be sure to specify top-quality insulation materials are used inside their transformers has to do with transformer designs which have evolved from previous decades when transformers were over-engineered and over-built. Driven mainly by cost/economic pressures to do more with less, modern-day power transformer designs deliver the same or higher operating performance as their hefty predecessors, but today's power

transformers are often smaller in size and lighter in weight with capabilities more closely aligned with operating needs.

These modern-day "efficiencies" were not achieved by accident, but rather by optimization and pushing the edges of design parameters which have significantly decreased the size of oil/flow/cooling channels, resulting in increasing demands and stresses on the critical magnet wire insulation. Significant cost savings in steel, copper and oil have been achieved at the burden of the single most important component to reliability and longevity of a transformer – the magnet wire insulation.

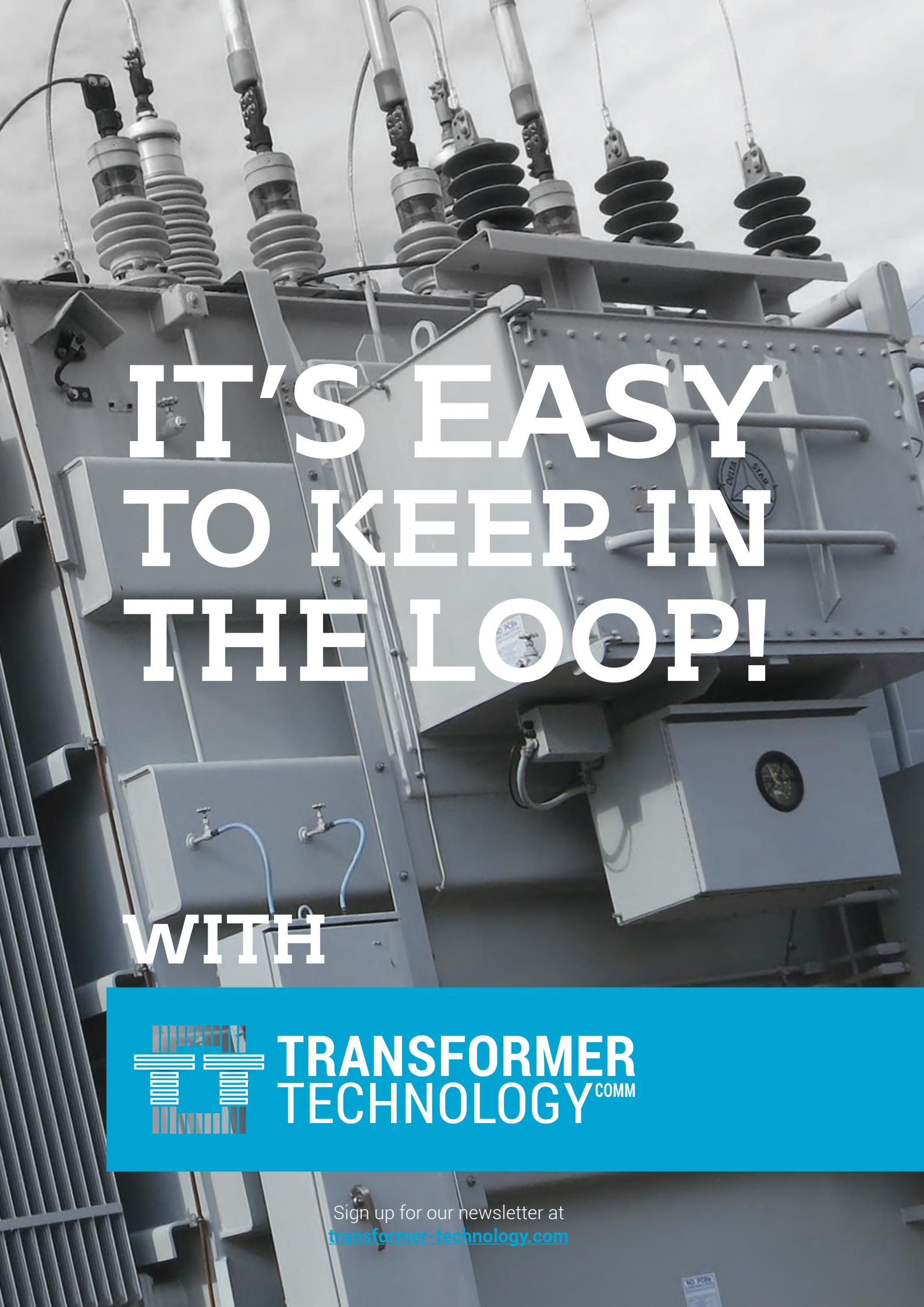
Yet another important reason why end users should be sure to specify that only top-quality

insulation materials are used inside their transformers is that today's power transformers are expected to operate well beyond the 20-30 year life expectancy of their hefty predecessors, while utilities now expect 50-60 years of reliable service from their fleet. This is despite leaner designed transformers, increasingly severe weather events, increasing electrical demands, increasing grid/transmission voltages and grid-resilience requirements, all of which place operation stress on the most critical component to transformer reliability and life expectancy – the insulation material.

Such expansion in life expectancy of power transformers is only possible with a combination of:

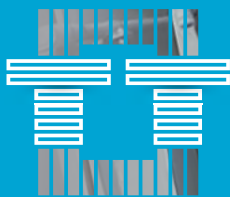
- Solid/reliable design which manufacturers provide
- Top-quality insulation materials
- Operational excellence supported by state-of-the-art monitoring

Significant advances in power transformer fault/alarm monitoring devices and systems is another reason today's power transformers – new and old – are able to operate many years longer than previously thought possible. Technology today provides power transformer asset owners the ability to monitor their most valuable assets in real time 24/7/365, allowing operators to quickly and precisely adjust and balance loading, whereby protecting the critical insulation system from life-shortening damage when overloaded and run too hot. Additionally, combined with regular oil testing, such monitoring systems provide operators with actionable mitigation recommendations to faults/alarms, which enable them to much better manage transformer performance and mitigate issues before problems grow to the point where asset life is reduced or critical damage occurs. Although equipping power transformers with sophisticated fault/alarm monitoring systems obviously increases the initial cost of the asset, these one-time costs are easily outweighed by the benefit of significant reduction of the total cost of ownership over the 50-60 year life of the asset.



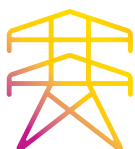
IT'S EASY TO KEEP IN THE LOOP!

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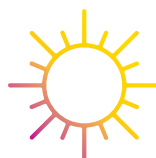
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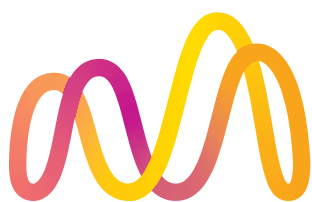
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Patrick F.

General Manager of
Andax Industries

Interview with **Patrick F. McAtarian**



McAtarian

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At Andax, we focus our energies on the electric utility and industrial markets, providing solutions that customers will not typically find off the shelf.

Andax Industries is celebrating over 40 years in business.

Andax Industries is celebrating over 40 years in business. In a recent Tech Talk, company co-owner and General Manager, Patrick F. McAtarian talked to us about what it takes to base your success on custom solutions and keep the family-owned business innovative and successful for decades to come.

Alan Ross: Patrick, your company boasts over four decades in the leak-and-spill control, secondary containment and emergency preparedness business. In my previous life, we once had a major oil spill. When I first met you, I didn't know that the remediation system we used to contain that spill was manufactured by Andax Industries. Tell us a little bit about what your company does.

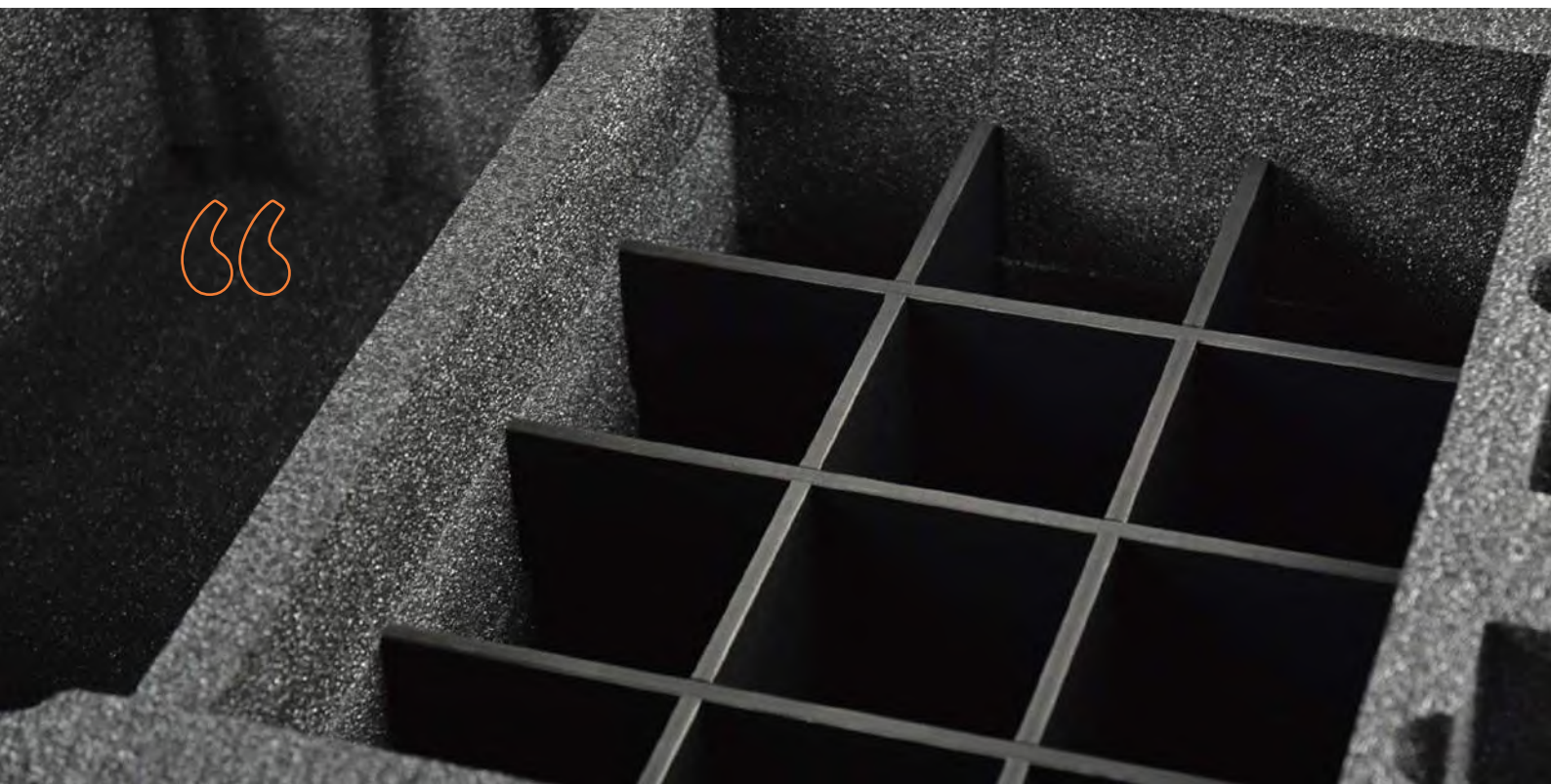
Patrick McAtarian: Thank you, Alan. Andax Industries has been in business for over 40 years. I co-own the company with my brother, as General Manager and head bottle washer. At Andax, we focus our energies on the electric utility and industrial markets, providing solutions that customers will not typically find off the shelf. That often involves custom applications that fit customers' particular requirements. We fabricate products and containment systems to meet their particular needs.

AR I understand that you produce custom-designed foam packaging for the shipping of electronic or laboratory equipment and other fragile instruments. Is that a special division of the Andax business?

PM That is one of the categories of products we offer. We found that our core customer base had many different needs, some of which could be fulfilled from a different perspective. An electric utility, for example, will have a need for testing equipment in order to test transformers for PCBs. To transport the samples needed for analysis and diagnostics, they would typically use a Pelican™ case, lined with anything from plastic wrap to rolled up newspaper. We created a custom case with precut foam to fit the fragile equipment. The foam ensures protection so that the equipment can be dropped off at UPS or FedEx and get to its destination safely.

AR I would like to know more about the heart and soul of your business. For privately held companies, companies where owners are involved, we find that vision is critically important to where they are going and how they present themselves to their customers, suppliers and employees. What is your vision for Andax Industries?

PM In previous conversations that you and I have had, Alan, I believe we both recognized the fact that there is a transformation



Our goal at Andax is to re-educate the customer base on the lessons that have been learned from the past on how to solve a particular issue, and to provide not only products, but also the methodology to keep utilities and their employees safe.





going on in the electric utility markets and other industries as well. Common knowledge is not as prevalent as it once was. We see that people are not thinking outside the box when trying to solve a particular problem.

Our goal at Andax is to re-educate the customer base on the lessons that have been learned from the past on how to solve a particular issue, for example, how to deal with the leaking pad mounted or overhead transformer. We feel that we are going to be able to provide not only products, but also the methodology to keep utilities and their employees safe and give them the proper tools to do the job right the first time. Our goal is to assist the electric utilities and help the line crews do their job.

AR One of the things I love about your approach is that instead of selling a product, you are selling a solution which starts with the problem. You design the solution around the problem.

You have a lot of different solutions, from large scale to smaller scale. All of that must have been created through innovation, the ability to

look at a problem and see how you can solve it in a different way. Tell me a little bit about how you handle innovation.

PM One thing that helps with innovation is listening to the customer. We both have a piece of the puzzle. They have the concern, and we potentially have the know-how on the application of materials, structures and engineering in order to address that concern and solve it. That is our focus - listening to the customer. They are the experts in their field and we can apply our knowledge to provide them with a cost-effective solution. For example, there is a lot of new technology coming out, but the majority of transformers out there still have oil in them. For the safety of the line crews, we provide a containment solution that allows them to work safely and efficiently and assure OSHA and DOT compliance.

AR Leak repair is a very big issue in some of the older transformers. If oil can get out, then moisture can get in, which deteriorates the transformer. I believe the future is bright for Andax because carbon-based oils are still used to fill most transformers,

especially in North America. What other areas within the electrical system do your products and services apply to?

PM We have a wide range of products that address concerns for electric utilities – from overhead pole mounts, through pad mounts, all the way up to substation units – and that makes for some very large containment bags.

One of our claims to fame has been the development of an insulator bushing sac that is designed to allow utility workers to lay down an insulator bushing when they take it out of service. They may be saving it because it is still in good condition and they want to store it for a couple of years, or it may be damaged and needs

to go out for remediation or disposal after being taken down. If they hadn't been leaking already, these bushings usually start to leak when laid down. Our product allows the utility workers to hermetically seal those insulated bushings and ship them out for disposal or storage.

We also have portable containment pools that help contain fluid in case of an accident during transport. A utility truck typically carries over 100 gallons of diesel fuel, 30 to 50 gallons of hydraulic fluid on the vehicle itself plus a radiator. If it gets into an accident, this may create a contamination issue since it usually happens over a storm drain. We provide instant portable systems that a line crew can put underneath a leak in less than three seconds to contain up to 150 gallons.



We provide portable containment pools that help contain fluid in case of an accident during transport.

AR I believe that the development of these solutions goes back to your vision and what makes you unique. If I were a customer with not just one problem, but with potential problems – how would you engineer a solution for me?

PM It goes back to experience which resides in the company. We have had decades of service in the electric utility market and insight into their concerns. Also, listening to the customer and getting what their main priorities are is very important.

Here is an example of a solution we recently designed to help solve the issue of lifting and transporting pole-mount transformers.

In order to make shortcuts to the work methods for lifting and moving pole-mount transformers, some utilities were using bags with straps and flexible intermediate bulk containers (FIBCs), claiming that the process would be DOT and OSHA compliant. DOT is very specific about what you can put into an FIBC, and a transformer is not one of them. FIBCs are designed and tested for materials such as soils, gravel or seeds.

This issue signaled a need in the industry for a change in the way transformers were being contained while lifted and moved. We at Andax Industries listened to our customer base, found out what their primary concerns were and realized that they needed a product that would allow them to contain the transformer while lifting it in a completely OSHA compliant manner, in accordance with the manufacturer's lifting lugs. Using alternative methods such as FIBCs makes for an unstable load, which can potentially cause a failure or a fatality.

We engineered a product that allows the utilities to have complete access to the lifting lugs of the transformer while moving it. We integrated a duffle cover system that allows closing up the transformer when taking it back to the yard, making it weatherproof so it can be stored outside while they are waiting for the transformer repair company or disposal company to come and pick it up, without having to necessarily store it inside. Engineering that solution also involved development of new materials that were not available at the time. Using high tech materials, we developed some unique welding processes



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We engineered a product that would allow our customers to contain the transformer while lifting it by the manufacturer's lifting lugs and in compliance with OSHA regulations.

to be able to manufacture the product. In the end, we provided the utility with a compact product that could fit into a storage compartment on a truck, enabling OSHA compliant lifting and containment of the transformer.

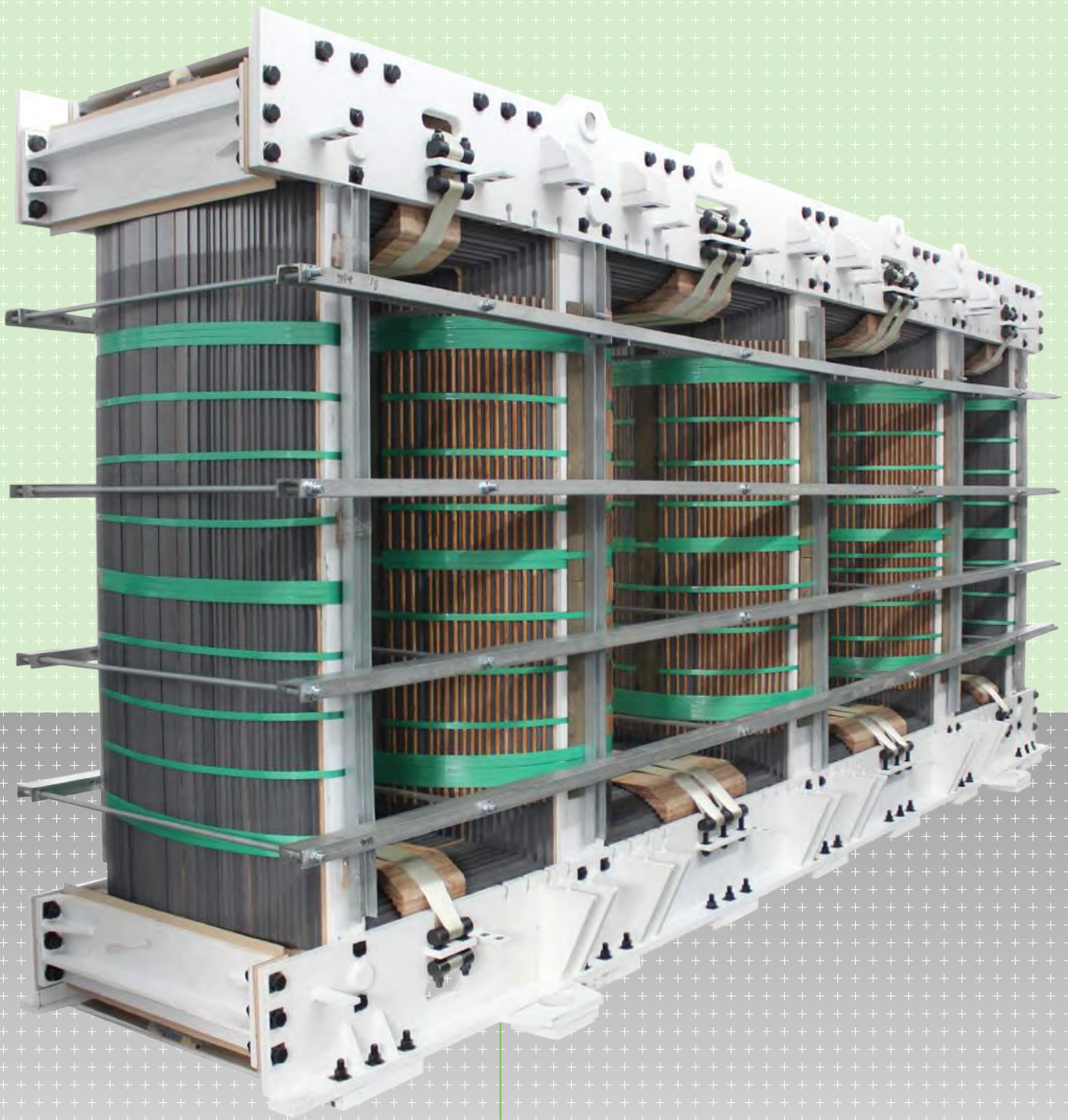
AR This means your solution also affects safety, which should be the number one concern of every utility. Is there anything else that you would like to share about Andax?

PM We are a family-owned company, now led by the second generation. We have been in business for well over 40 years and we plan on being around for another 40, God willing. You only get to do that by providing quality products, answering your customers' concerns and standing behind your product. That is what

we do at Andax every day. We value family, being able to go home at the end of the day. We want to do our part to make sure that our customers can do that as well.

AR We at Transformer Technology appreciate the companies that transfer experience and knowledge from one generation to the next. There is a lot of generational change underway in our industry and a lot of talk about how to bring young people into our niche business. It will be interesting to follow Andax as you introduce the next generation of engineered products. Patrick, thank you very much.

PM Thank you, Alan. I appreciate the opportunity.



VIBRATION AND NOISE REDUCTION OF TRANSFORMERS



PTTX'S ARTISAN SPIRIT OF "DARING TO BE THE FIRST"

Having conducted multiple experimental research studies on the factors that cause core vibration, and following our "artisan spirit", PTTX has put forward solutions and guidance for the transformer core industry that address a technological issue of vibration and noise reduction. This paper introduces the contributions made by PTTX in the industry – optimization of silicon steel sheets processing performance and core assembly parameters.

In recent years, with the continuous expansion of power networks and urban development, it is becoming more and more common for small and medium-sized transformers to be installed in residential and commercial areas or other application scenarios. These transformers generate noise pollution, affecting the lives of residents nearby. Therefore, vibration and noise reduction have become a special concern in the transformer industry and other supporting industrial chains.

According to research studies, transformer noise is mainly caused by the vibration of the transformer and its cooling system, and its intensity is associated with the transformer capacity, silicon steel sheet materials, core structure, magnetic flux density, and vibration performance of the cooling unit.



In fact, the vibration of transformers is mainly caused by core vibration, which is brought about by the following two factors:

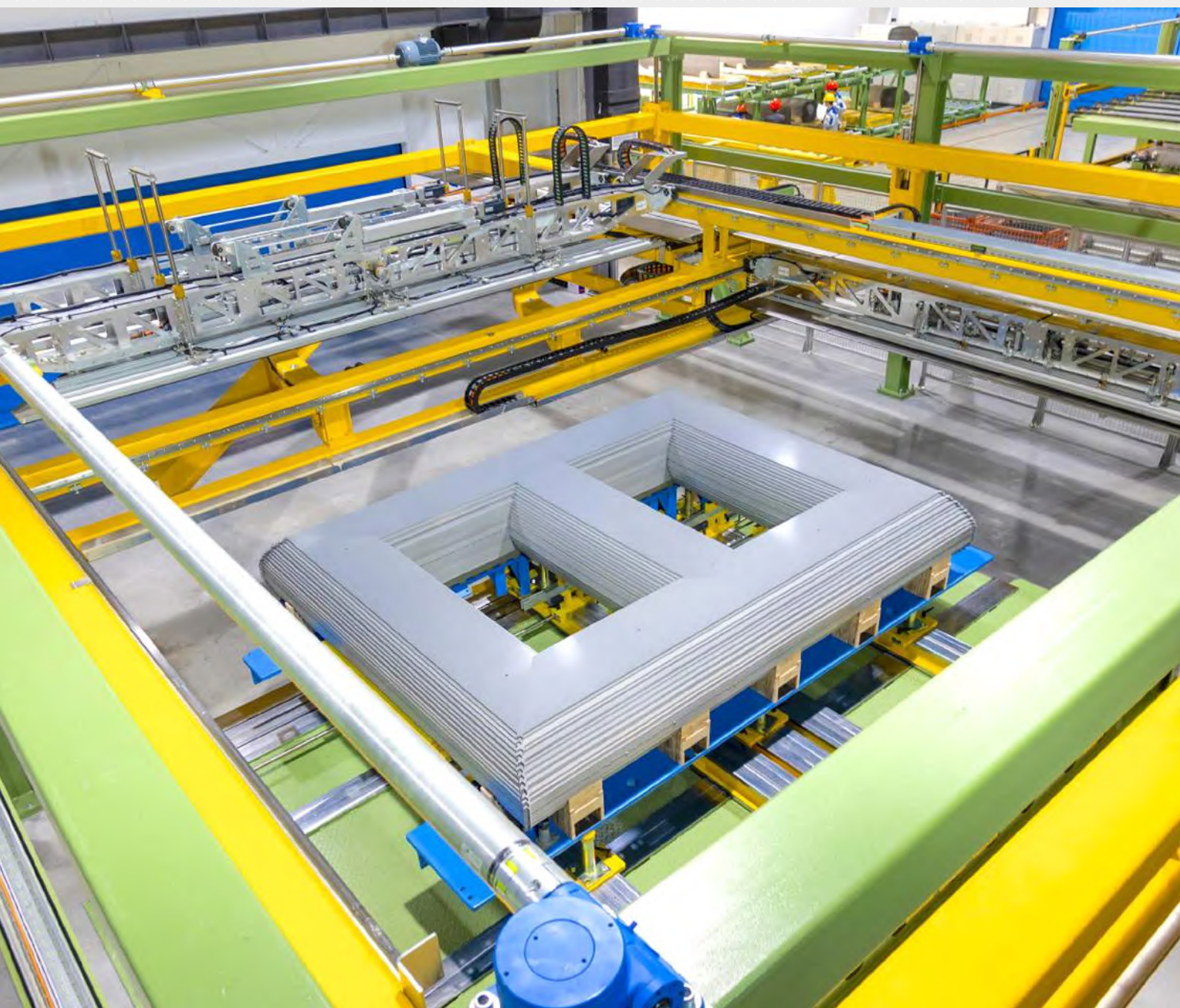
1. The first is the core vibration due to the magnetostriction of the silicon steel sheet;
2. The second is the longitudinal traction force caused by the distortion of the magnetic line of force at the joint of iron core and the side thrust caused by an uneven magnetic flux distribution in the iron core between silicon steel sheets.

In view of these two main factors of influence, PTTX has concentrated our efforts on optimizing the processing performance of silicon steel sheet material and the assembly process of iron core, thus providing guidance and making explorations for the technological transformation and environmental protection production in the transformer core industry.

Internal stress and magnetostriction reduction of the silicon steel sheet by automatic and serialized production

PTTX cores are made of high-quality cold rolled grain-oriented silicon steel sheets insulated by mineral oxide. In the actual application of the silicon steel sheet, a lot of care is paid to the influences of the magnetostriction and magnetic conductivity on the finished core products. Therefore, special measures are taken to mitigate the influence of processing on the silicon steel sheet in terms of stress characteristics, end flatness and thickness uniformity.

Magnetostriction is the root cause of core noise. In this regard, PTTX has invested over \$46.3 million to build a smart core factory able to maintain constant temperature and humidity, which has become our country's leading demonstration center in the transformer core industry. In the factory, smart stereoscopic warehouse logistics devices are used to provide full process automation from the storage of electrical steel raw materials to the stacking of finished core products. During the process, soft-contact procedures are used to handle all electrical steel materials – this means that we do not use a crane to lift products and our personnel is not involved in direct production or touches the electrical steel during the entire process. This helps reduce the generation of silicon steel sheet stress, thus ensuring the flatness and thickness uniformity of the end surface and reducing the joint by stacking steel sheets one by one, all of which results in noise reduction.





In addition, the serial production mode of “edge-yoke-edge-yoke-column” for the cut-to-length line of fully assembled cores denies the “two-step” mode of the traditional core sheet production (upper/lower yoke, left/right/center column), thus minimizing the issue of thickness difference of five columns existing in the traditional core sheet production mode. While ensuring the uniform thickness of silicon steel sheets, the slitting machine set is equipped with on-line iron loss and thickness detectors, intelligent stereoscopic warehouse logistics equipment and fully automated packaging line for fixed-size silicon steel sheets, which further reduces the influence of human factors on the performance of silicon steel sheets and helps achieve vibration reduction.

Compared to the traditional process, PTTX uses lean, serial, and smart automatic production devices that reduce all the process coefficients by 5% in silicon steel raw materials, iron core manufacturing and assembly, helping us meet our customer needs and reach product performances.



Assembly parameters re-defined based on multiple research

PTTX technology R&D team carried out the analysis of the relationship between core assembly parameters and clamping force between silicon steel sheets, as well as the mechanical analysis of the cores under pre-tightening torque assembly conditions and binding process conditions. The results led to the conclusion that the clamping force between iron core pieces can be controlled by assembly parameters.

PTTX also conducted research on the influence of pre-tightening torque and binding process on core vibration. The results showed that the core assembly parameter is associated with the core capacity in a qualitative way. With the increase of core capacity, the pre-tightening force of core assembly, assembly torque and the number of binding strips increase as well, while the spacing of binding bands decreases.

Based on the above findings, PTTX performed analytical statistics on the structural parameters and assembly parameters of different types of cores produced. Taking the dry-type transformer core as an example, the bolt torque and binding parameters were determined for various types of cores with capacities from 100 kVA to 800 kVA, 800 kVA to 2,000 kVA, and 2,000 kVA and above.



Through tests PTTX established that in the actual production, considering the on-site equipment and materials in the workshop, adopting different assembly parameters on corresponding cores with different capacities can effectively control the vibration and noise of the transformer core, improve the qualified rate of products and reduce economic losses caused by rework, which is of great significance for achieving lean production of transformer core assembly and improving the production efficiency.

Cooperation between universities and industry is a practice PTTX has always followed since its establishment. The company established a long-term cooperative laboratory with Xi'an Jiaotong University. Since 2016, the company has played an exemplary role in the Study on Vibration and Noise of Core Process Holes, Research on Influence of Pieces Stacking Method on Core Noise of Dry-type Transformer, Experimental and Simulation Study on Influence of Bolt Tightening Sequence on Transformer Core, Experimental Study on Influence of Bolt Torque on Transformer Core and Research on Influence of Assembly Parameters on Transformer Core Vibration. The technological advancement steps that have been studied and demonstrated can serve as the guidance for the development of the industry.

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Xishan District, Wuxi, China****PTTX Global Offices:****Headquarters: Wuxi, China****European Office: Frankfurt, Germany****Middle East Office: Dubai, UAE**

John F. Darby

President of **Niagara
Power Transformer**

Interview with **John F. Darby**

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Investing in relationships is the key to our success today and fundamental to the vision of how we are going to be successful in the future.



Following the recent rebranding of Niagara Transformer to Niagara Power Transformer, and the start-up of a new arm of the business that will take on repairs, we talked to the third-generation CEO, John Darby, about the company's history spanning nearly 100 years, their unique value proposition and the vision for the future and the next generation.



Alan Ross: John, I am fascinated by companies that have been in business as long as Niagara Power Transformer has. The company is nearly 100 years old, would that be fair to say?

John F. Darby: Correct, we are approaching our 100th anniversary in 2024. Our history goes back to 1920 when my great uncle emigrated from Guelph, Ontario into the Buffalo Metropolitan Area. Those who know the history of the industrial Great Lakes know that this was a very vibrant area of the country. There was a tremendous amount of industrial infrastructure

built up around the Great Lakes and Niagara Falls. My great uncle opened a business in 1924, primarily to do repair work on motors, electromagnets and switchgear transformers for that heavy industrial base that surrounded the Great Lakes.

In the late 1920s, our industrial customers began asking us to consider making new transformers to fill a market void. A few years later, in 1933, we began making new industrial transformers, followed with an expansion ten years later into the utility-grade transformer market.

This dichotomy between making heavily engineered industrial transformers and sophisticated utility transformers that we do today has lasted almost 100 years.

AR That is amazing. I remember we joked about this: I usually say that in my opinion the best transformers were made by a company called Westinghouse back in the 1970s. And you said they were not; they were made by Niagara Transformer and they just put the Westinghouse label on them. So in fact, for the last 15 years I have been saying the best transformers were made by Niagara Transformer back in the 1970s, which would indicate that you have a vision for the future.

JD As you approach the 100th anniversary with three generations leading the company, you focus to a certain extent on your history. But obviously, you also focus on what the next 100 years are going to look like. We are in an interesting apex between history and future. It gives us a good opportunity to go back and think about what our vision for the future is and how we are going to interpret that in a rapidly changing business climate.

What is old is new again encapsulates our vision. The first utility customer that we started doing business with in 1943 is still an active customer today, more than 75 years later. You might ask yourself how we achieved that long-term partnership. We did it by living two words: *Relationships matter*.

The first utility customer that we started doing business with in 1943 is still an active customer today, more than 75 years later. You might ask yourself how we achieved that. We did it by living two words: *Relationships matter*.

Even in the digital age of Zoom, we feel that long-term relationships really matter in our business and our industry. We like what we call *long-term marriages* with our partners and our employees, and certainly with our customers. We think that investing in relationships is the key to our success today and fundamental to the vision of how we are going to be successful in the future.

AR That is the hallmark of excellence. Another thing the customers look for is a unique value proposition. What is it that Niagara Power Transformer brings to the marketplace?

JD As implied by our long-term perspective in relationship building with our customers, we are not transactional in any way and our value proposition really underscores that. The way we compete and live our Relationships matter mantra is accentuated by four attributes that we see as a four-legged stool.

Number one, we think we have the best people in the industry. It starts with our technical ability and our deep engineering. We love taking on tough engineering challenges. In today's world where so many manufacturers are very focused on a specific product type, we are just the opposite. We are what you call high mix, low volume. We will take on engineering challenges that others, even much larger and much more complex organizations, do not have the engineering bench for. That is how we did so much private labelling, not only with Westinghouse and GE, but also with Square D over the years, because even though they were competitors some days, they were also very good customers other days.

We lead with quality in everything that we do. You can do unique and tough engineering challenges, but if you don't put quality first, then the engineering doesn't really matter. And we do all that in very competitive lead times.

We are responsible for the specification of those transformers as well, selecting the suppliers and ensuring that the designs are in accordance with our requirements. We conduct design reviews and perform all factory acceptance tests. But the actual asset management and the maintenance of the operation belongs to the field staff and their management.

Being able to rotate people, taking on tough engineering challenges, executing with incredible quality and meeting customer-defined lead times – these are the four attributes that we compete on and that encapsulate our *Relationships matter* mantra.

Obviously, we are sensitive to a lot of the continuous process industries that we deal with on the industrial side, such as steel, electrochemical and mining. We operate 24 hours a day, seven days a week, 365 days a year so we can meet their schedule. Being able to rotate people, taking on tough engineering



challenges, executing with incredible quality and meeting customer-defined lead times - these are the four attributes that we compete on and that encapsulate us.

If any of your readers have an engineering challenge that nobody else will take on, we likely will.

AR Excellent, we will make sure our member companies know that when they have a need for an engineered-by-design solution.

In order to do what you have been doing for three generations, there had to be next-generation knowledge passed on. It is the knowledge that you have, the knowledge that your engineers have, and that the workers have. We are all facing the same problem: How do you prepare the next generation? How do you recruit them? After that, how do you prepare them to handle the problems that are changing all the time? What is it that you at Niagara do to be able to approach this need for next-generation transfer of knowledge?

JD In our particular case, it all starts with the leadership team. Our company is not only almost 100 years old, but it is also approaching the fourth generation transitioning into the business. My son, who is finishing his studies at Cornell University, has already begun to plug in and learn the business from my point of view. But I can tell you, he looks at human resources and many other things very differently than I do. It is reassuring, because I did the same thing with my dad and he in turn did the same thing with my great uncle, who started the firm. It is a balancing act. Having an equal measure of interest and aptitude in the business like ours, I think is essential.

At the same time, we want to be open to being innovative. We want to be open to applying those fundamental business and engineering skills in new ways in a rapidly changing environment, not only for suppliers and customers, but also for employees. As we all have lived through this last year of significant and almost unbelievably quick changes and challenges, the last year has really underscored that.

Preparing the next generation starts with being open to new innovative ideas, while having the family at the core. That provides the underpinning of how we approach not only recruiting technical engineers from all over the world, but also our local and national people that supply our direct labor talent.

We are very selective about who we hire, even in today's very competitive marketplace for our top labor, and we underscore that with family approach. Again, using that term long-term marriage, we want to make sure that it is a partnership not just for the company, but also good for the employee. And we spend a tremendous amount of time in the selection process.

When somebody comes on board, we invest a lot in giving them numerous ownership opportunities, from the most junior person on the production floor, all the way through engineering. That way they have a sense that the family has their back, and they have a sense of ownership. We don't want transactional employees. We want people who are long-term committed to quality and to our success. And that is also what we look for in customers.

If any of your readers have an engineering challenge that nobody else will take on, we likely will.

We have had employees who have been with us for 30, 40, 50 years. We even had an employee of 55 years. We have less than 0.5% turnover, which in today's marketplace is absolutely unheard of. We tend to be very selective and make decisions looking at both sides of the employment. We do a lot of training and engagement. And the results, I think, speak for themselves, at least in our business where we have a lot of long-term and committed employees. If you choose not to be a transactional company, then you cannot be transactional in engaging your workforce either.

AR Let's talk a bit about the future. One of the things that impresses me about Niagara Power Transformer is that you are a company based in a tough state. To do business in New York is not the easiest. You are an American manufacturer, American-made, but you are also a global supplier to a marketplace which is fast becoming even more global because the need for uniquely designed solutions.

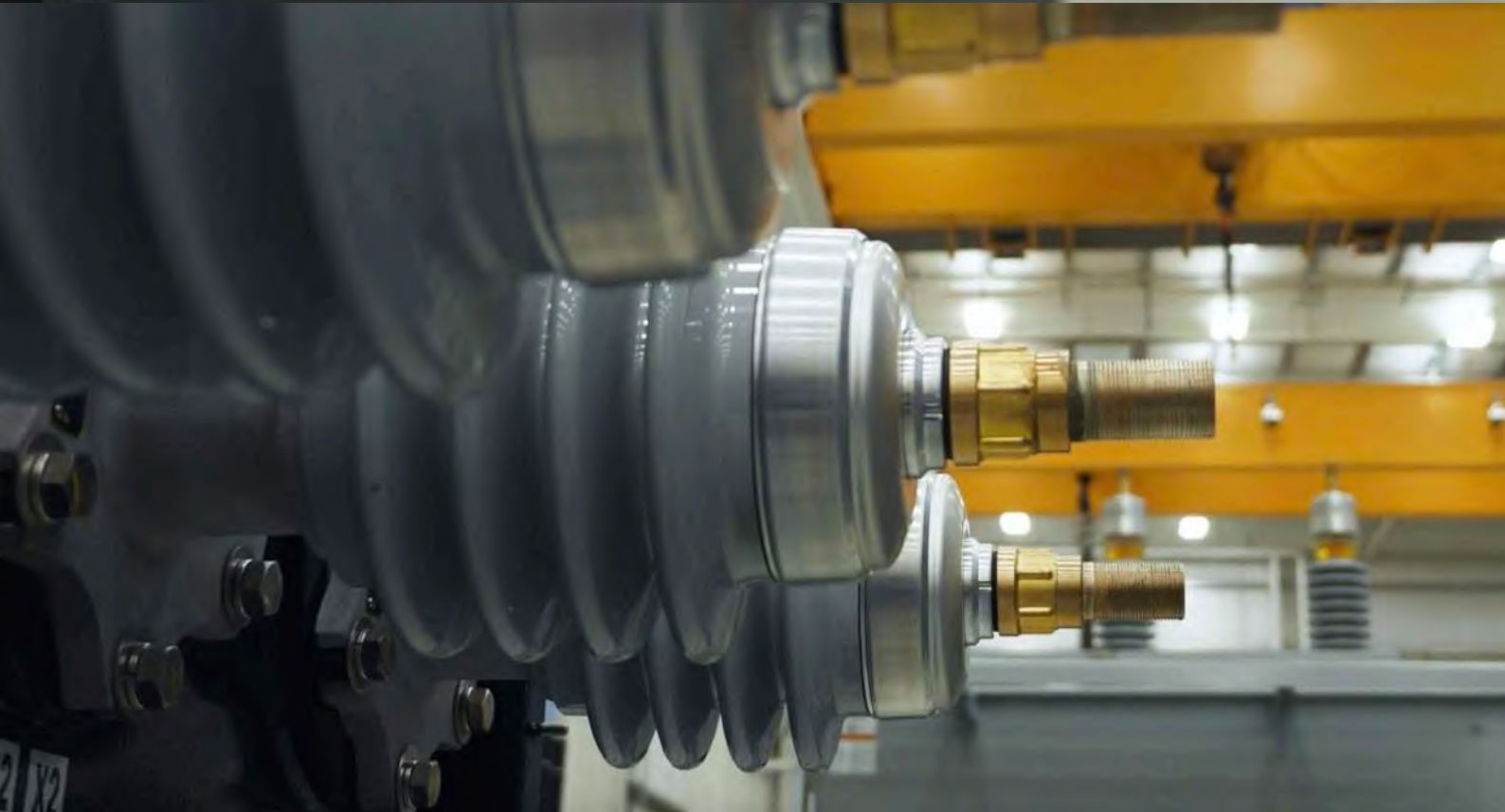
Take yourself a decade or two out. What do you think is happening in our industry and how are you connecting with it?

JD There are some very exciting things going on that I think we as a company can take advantage of. You pointed out that we do our manufacturing in the United States, but we do have design offices in China and Canada. We are very familiar with taking advantages of the expertise and inventory in other parts of the world. But we convert that into our own execution here in the U.S. It is a very exciting time to take those strengths and channel them inwards, because there are a number of interesting things that are going on.

The electric vehicle market is just in its infancy. That is going to be a tremendous, sustained market opportunity for those in our space. Here in New York State, we are pushing for 100% renewable generation. I think there is still a lot of runway left for renewables, particularly solar and battery storage. I believe that presents us some great opportunities, a bipartisan US infrastructure bill that is being discussed in the Congress and the Senate led by our new president, Mr. Biden. That obviously would be very exciting in terms of making investments in energy efficiency, infrastructure, redundancy, and continuing to replace aging infrastructure that is long overdue.

Finally, I think that there is a sense of uncertainty among our North American customers, and to some degree our European customers, who are concerned about stretched supply chains,







particularly those that have pursued 100% Asian-oriented supply chains. They are concerned about access to products, technical support, and to a quick and nimble response in case there is a problem. I think that demographic shift is never going to go back to what it was in the 1950s, nor do I think we want it to.

We are excited about reaching 100 years in business and the fourth generation taking over.

There is a movement back to really taking a hard look at redundancy and supply chains. Certainly, Asian competitors offer a lot of cost advantages, but they are not a one-stop solution to all potential problems that our more sophisticated customers are recognizing. I do think that shortening up supply chains and providing redundancy to supply chains that our focused outside of the North American

market will enhance and sustain our business going forward.

We are excited about reaching 100 years in business and the fourth generation taking over. I think we are well positioned as a company. We are healthy. We have invested \$45 million in our plant and equipment here in Buffalo. We have one of the world's most state-of-the-art facilities to take on the opportunities that the macro environment is going to rapidly present. I am very excited about our prospects, and I believe that we will balance our old school value system against the opportunities that are rapidly evolving and presenting themselves to our market.

AR What is old is new again. Thank you for these fantastic insights, John.

JD Thank you very much Alan, we appreciate the opportunity.

Protection and Control Commissioning: Two Steps Forward, One Step Back

by **Kenneth L'Esperance**
and **Jeff Hardin**



Ken L'Esperance, P.E., has 40 years of experience in the energy industry. He has held many upper-level engineering positions and owned his own engineering consulting company from 1987 to 2014. He is currently the director of the engineering services division of RMS Energy Co., LLC. Ken has his NETA Level IV certification from the International Electric Testing Association (IETA) and is certified on 138 kV, 69 kV, 13.8 kV, 4.16 kV, 480 V, and 208Y/120-volt systems, including designing, testing, commissioning, and troubleshooting. He holds a Bachelor of Science in Electrical Engineering from Michigan Technological University.



Jeff Hardin, electrical engineer, is a dedicated technical leader with nearly 20 years of experience in the energy industry. He is experienced in utility design and operations and has extensive training on NERC standards, NETA testing standards and NFPA 70E standards. He has held many senior level positions for consulting firms and a utility, and currently serves as vice president of sales and estimating for RMS Energy Co., LLC. Jeff has a Bachelor of Science in Electrical Engineering from the University of Kentucky.



THE ENERGY INDUSTRY IS MOVING FORWARD AT WARP SPEED ON TECHNOLOGICAL AND INFRASTRUCTURE CHANGES. YET, THE PUSH FOR THESE ADVANCEMENTS HAS CREATED A MAJOR GAP AMONG THE RESOURCES THAT PROVIDE PROTECTION AND CONTROL COMMISSIONING SERVICES ON POWER SYSTEMS, WHICH BOILS DOWN TO LACK OF TRAINING AND SYSTEM KNOWLEDGE.

During the past decade, the energy industry has undergone major transformations in infrastructure redevelopment and the introduction of game-changing advancements in power systems technology.

With these major leaps forward, the important process of protection and control commissioning, which verifies, documents and places into service newly installed or retrofitted electrical power equipment and systems, has become increasingly critical.

Yet, the push for these advancements has created something of an unfortunate and unforeseen gap in the industry.

Many qualified personnel who truly understand protection and control commissioning are becoming harder to find due to retirement of the aging workforce and a smaller number of young professionals entering to replace them. This reduction in experience and knowledge in some quarters occurred as the technology vastly improved, while training and certification programs for technicians substantially lagged behind. In fact, what used to take seven to 10 years of intense education, mentoring and final certification have been compressed into just a few years as a way to catch up. This has created a production line of less qualified technicians who may not possess the required knowledge or comprehension of the commissioning process and the very equipment that needs inspection. Deep understanding of protection and control standards, NERC, new technologies, a reconfigured power grid system and the equipment itself, are requirements among technicians necessary to be proficient and accurate in their commissioning work.

One simply needs to look at the new processes and advances in relay equipment to get a view of how things have changed in commissioning services. The baseline of protection and control standards has always revolved around electromechanical relays, the true marvels of technology that are as old and dependable as those who invented or improved upon them, like Tesla and Edison.

These protective relays work between normal and expected operating conditions and the inevitable system faults that come with any power distribution system. The tried-and-true electromechanical relays detect power system conditions and provide a measured and appropriate fault response with repeatability and reliability during decades of in-service time. Electromechanical relays are still considered to be amazing technology, and those who invented them are responsible for the kind of reliability and safety that our power systems enjoy today.

The Reliability of Electromechanical Relays

There are myriad faults that can be detected by electromechanical relays. Over voltage, under voltage, differential faults and distance sensing for line protection are just a few that will generate the fault condition necessary for the relays to take action. ANSI and IEEE have standardized relay function codes such as "50/51," which speak the power engineers' language for instantaneous overcurrent (50) and time overcurrent (51), signaling a



command to trip a circuit breaker when line current becomes excessive, avoiding severe overheating or even fire.

This dependable relay technology hasn't changed much, as it has been the foundational workhorse for decades; that is, until the advent of solid state and micro-processor-based relays. With all the change in the power industry, the major downside of electromechanical relays has become the limitations of its inherent single-element functionality, which is designed to detect faults for

only one particular element. This limited functionality simply requires that far too many relays must perform the fault functions needed to ensure that today's more advanced and complex power distribution systems continue operating at peak efficiency.

Another drawback of electromechanical relays is that they require periodic testing and calibration. These relays depend upon mechanical motion, so maintenance on the relays themselves is required to produce accurate and reliable core operations,

such as opening a circuit breaker or tripping a lockout device when needed.

The bottom line is that power systems can run a long time without a fault ever occurring. But with power systems, an industry axiom is that trouble is always brewing. When the time comes for a failure, and it will come, a dependable relay or series of relays are necessary in order to accurately detect the fault, act upon it, and perform the function needed that avoids system damage and costly outages.

DEEP UNDERSTANDING OF PROTECTION AND CONTROL STANDARDS, NERC, NEW TECHNOLOGIES, A RECONFIGURED POWER GRID SYSTEM AND THE EQUIPMENT ITSELF, ARE REQUIREMENTS AMONG TECHNICIANS NECESSARY TO BE PROFICIENT AND ACCURATE IN THEIR COMMISSIONING WORK.

Solid State and Microprocessor Relays

The creation of solid-state relays, which don't rely on mechanical motion, was a step forward in replacing the mechanical motion of its predecessor. But the industry did not dwell too long on solid-state relays, because they also required calibration and maintenance.

It was not until the microprocessor became more affordable and dependable that the industry witnessed bigger leaps forward in protection and control. These digital marvels leave the analog world behind, with their ability to rely on more accurate and sustainable digital technology that perform multi-function protection protocols, putting the proverbial "many eggs into one

basket." Of course, with so many functions embedded into a single relay, a rare failure of such equipment can produce wider scale and less contained damage compared to electromechanical relays.

Microprocessor relays include a flexible selection of parameters that make them an easier application in the power system, and the provision of more accurate data. There are three important parameters available in such relays, including response characteristics, sensitivity, and selectivity.

Response characteristics are now a family of curves allowing for a variety of customized characteristics that can be monitored and measured. The selection of parameters can provide **sensitivity** for a wide range of

operating conditions, and **selectivity** needed to prioritize response between protective elements and upstream and downstream devices. These microprocessor relay protocols are major advantages within today's complex and more advanced power system solutions.

The complex digital algorithms needed to realize these multi-functional benefits now require another level of understanding for the technician to attain. These attributes, along with the programmable logic elements and the complex communication technologies within microprocessor relays, allow for intricate networking and reporting capabilities and demand a working knowledge in many technical realms.

Integration of supervisory control and data acquisition (SCADA) also creates

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a large pipeline of collected data. Operators are no longer flying blind when such integration provides critical data on operating currents, fault oscillography, power factor, min/max data and other critical parameters.

Required in any successful commissioning effort is complex and up-to-date testing equipment, including multiple independently controlled voltage and current channels; independent phase relationship control of all channels; and accurate reporting of results as the test is being conducted.

Starting with a Good Plan

A good commissioning plan begins with the realization of the benefits of the power systems in play. To realize reliability and predicted response,

technicians must test not only the relays involved, but also the system in which they reside. **This is often where industry resources lag, because operating a test set is very different from the essential aspects of understanding what the test set is actually doing while performing a test on a particular relay or relay element.**

Technicians who are new to the field or have not had the proper indoctrination into the inner workings of a modern commissioning process will be challenged to create an accurate and positive outcome in even the most basic commissioning projects. For example, while a relay test system (RTS) can be run for an overcurrent test, a complex power scheme that includes differential protection, energy calculations, and other factors needs to clear through a comprehensive plan to

ensure the plan is both solid and valid. This authentication of commissioning plans comes with comprehensive knowledge and deep understanding of the relays and how they relate to complex power systems. Without this knowledge set, the accuracy of the test is relying on the test itself, with little to no input from the technician to guide the analysis toward a comprehensive and successful conclusion of the commissioning project.

Understanding Elements of Proper Commissioning

To conduct proper commissioning on any power system, a full understanding of the following elements is essential for a positive and accurate outcome:

Zones of Protection

Current Transformer Characteristics

- a. Saturation curves
- b. Accuracy class considerations
- c. System burden considerations

Breaker response and timing

Redundancy for enhanced reliability

Functional testing – programmable logic elements

Trip equations

SCADA systems

- a. Communications capabilities
- b. Fiber networks
- c. Site DSC considerations

A solid commissioning plan will include a physical checkout from point to point. Testing of wiring and its configurations is the first step in any good plan, to ensure wiring is properly installed. Today, utilities have control houses prebuilt offsite and subsequently dropped into place, a major step in efficiency for both time and money. However, this is where assumptions get made – that wiring is predestined for proper installation. But nothing could be further from the truth. Wiring is where things go wrong both early and often, and not checking every single point and connection upfront will substantially hamper any proper commissioning plan.





Conclusion

Any industry resource that conducts thorough and accurate protection and control commissioning and adheres to proper protection and control standards will employ technicians and other experts who have the proper years of experience to accommodate for the more complex power systems we have today. Commissioning companies must not only recruit the right people and pay them appropriately, but also invest in ongoing development and training to ensure every commissioning job takes on the best and most accurate commissioning approach.

Ensuring the proper outcome of a commissioning project has various aspects that include the right testing equipment and plan, coupled with technicians who have the experience and knowledge to apply to ensure protection and control standards are achieved. It's only a matter of time when the industry catches up and starts to churn out more qualified technical personnel; but until that time, choosing a commissioning partner based on their technicians' expertise and knowledge base is a critical aspect to ensuring the safety and reliability of modern complex power systems.

ANY INDUSTRY RESOURCE THAT CONDUCTS THOROUGH AND ACCURATE PROTECTION AND CONTROL COMMISSIONING AND ADHERES TO PROPER PROTECTION AND CONTROL STANDARDS WILL EMPLOY TECHNICIANS AND OTHER EXPERTS WHO HAVE THE PROPER YEARS OF EXPERIENCE TO ACCOMMODATE FOR THE MORE COMPLEX POWER SYSTEMS WE HAVE TODAY.



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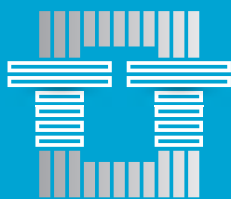
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