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**SUBSTATION SOLUTIONS AND
POWER SYSTEM DYNAMICS:**

ELECTRIFICATION & UNDERGROUND CABLING



**TRANSFORMER
TECHNOLOGY** MAG

TRANSFORMER TECHNOLOGY MAG

Enhancing Medium Voltage Power Cable Reliability through Non-Destructive Partial Discharge Measurements

It's time to build extra grid resilience into substation strategy

Interview with **Jason Neal**
President of Hyosung HICO and
Vice President of HICO America

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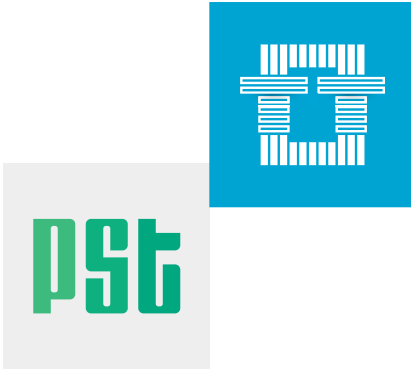
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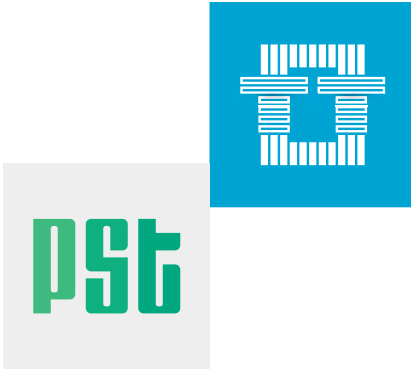


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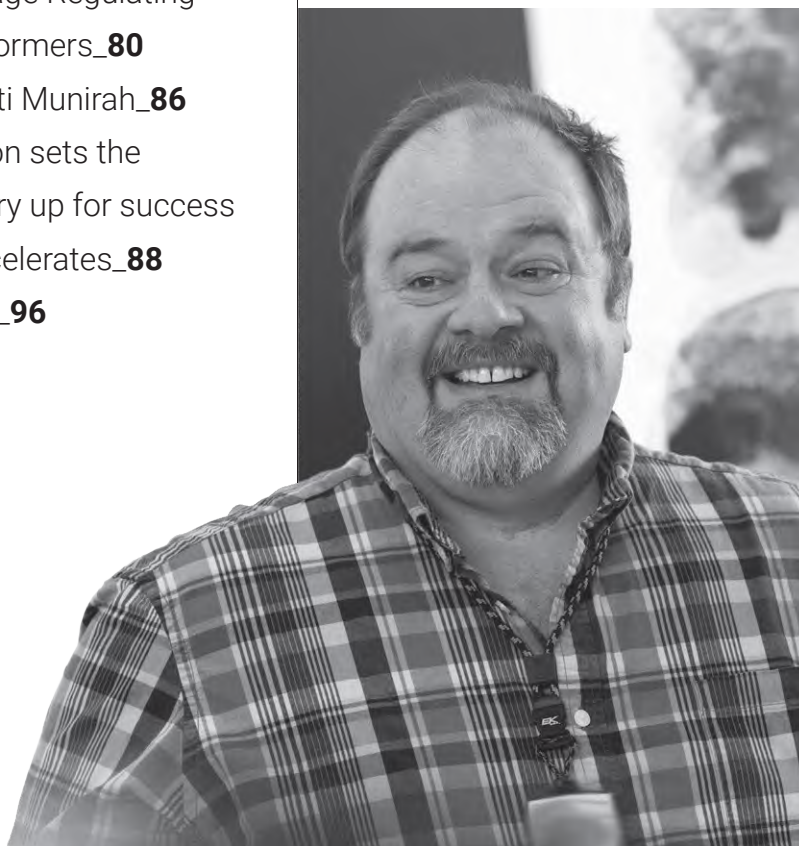
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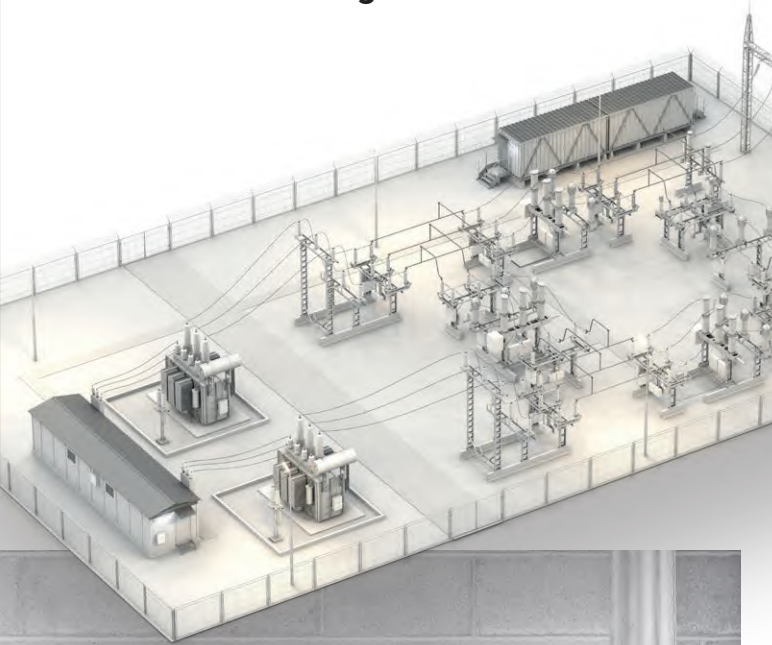
Senior Technical Advisor, Pacific Northwest National Laboratories

Advancing Battery Technology, Grid Resilience, and Sustainable Energy Solutions



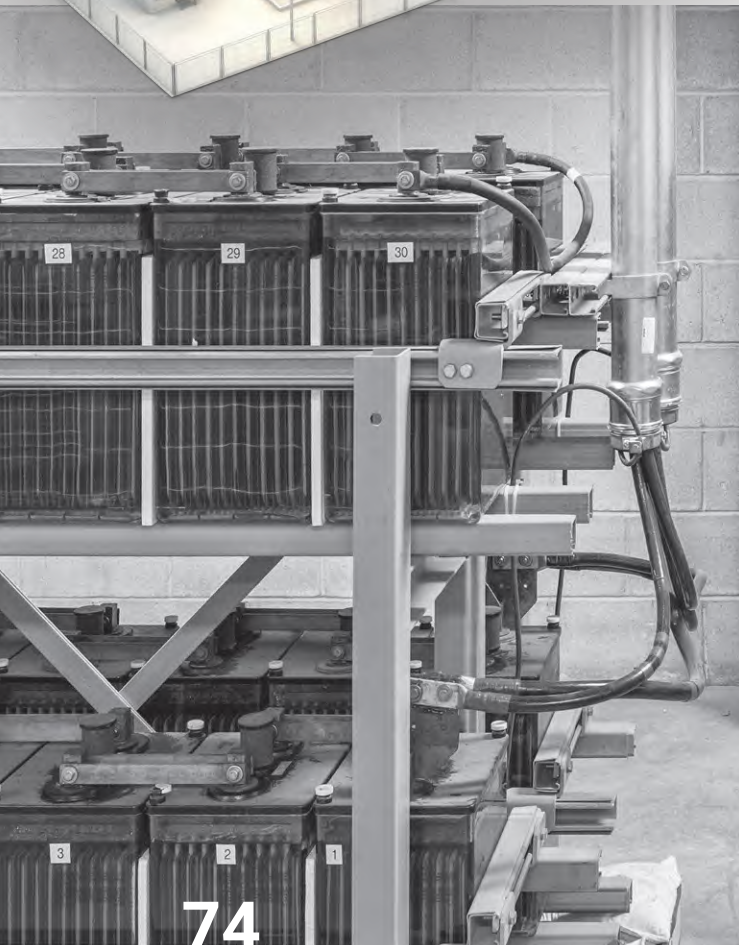
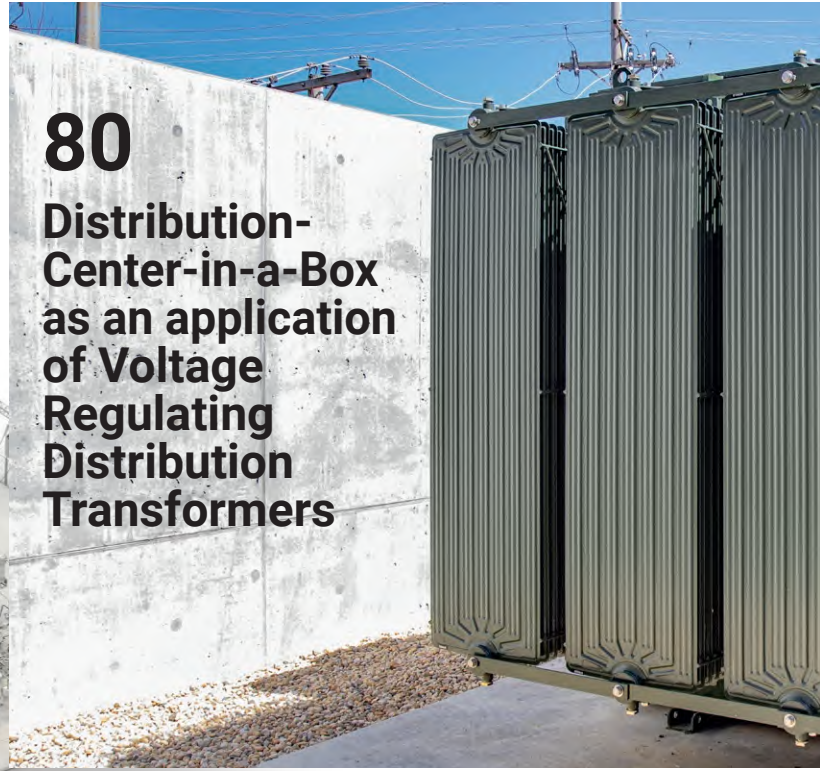
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Harmonic mitigation sets the transformer industry up for success as EV charging accelerates



BUSHINGS & COMPONENTS: LTCs, GAUGES, CONTROLLERS...

In October we focus on Bushings & Components (LTCs, Gauges, Controllers). It is one of our annual favorite issues and we have added new advances in other transformer components like LTCs and controllers.

In our October edition, we explore the **critical role** that **transformer bushings** and components play in ensuring the efficient and reliable operation of power systems.

From their vital function in **electrical insulation** and **support** to their impact on the overall **performance** and **longevity** of transformers, we **unravel** the **complexities** surrounding bushings and components.

Bushing technology is also adapting to new demands with new materials and manufacturing processes that the professional engineer must keep track of, so while much of the editorial space is spoken for, if you have an article, perspective or interview you would like to submit, please reach out to me at alan.ross@apc.media as soon as possible. We will be closing editorial content soon.

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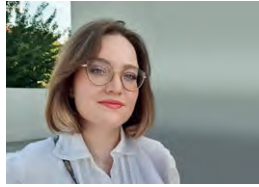
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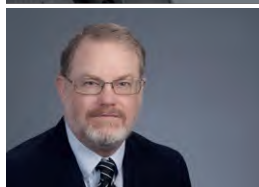
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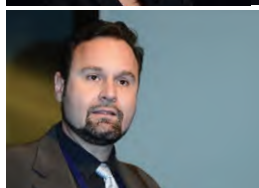
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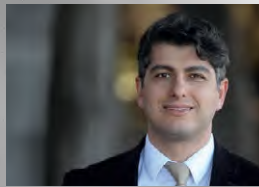
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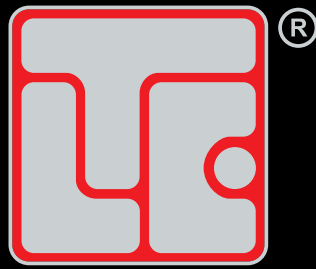


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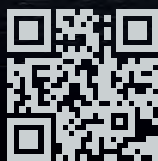
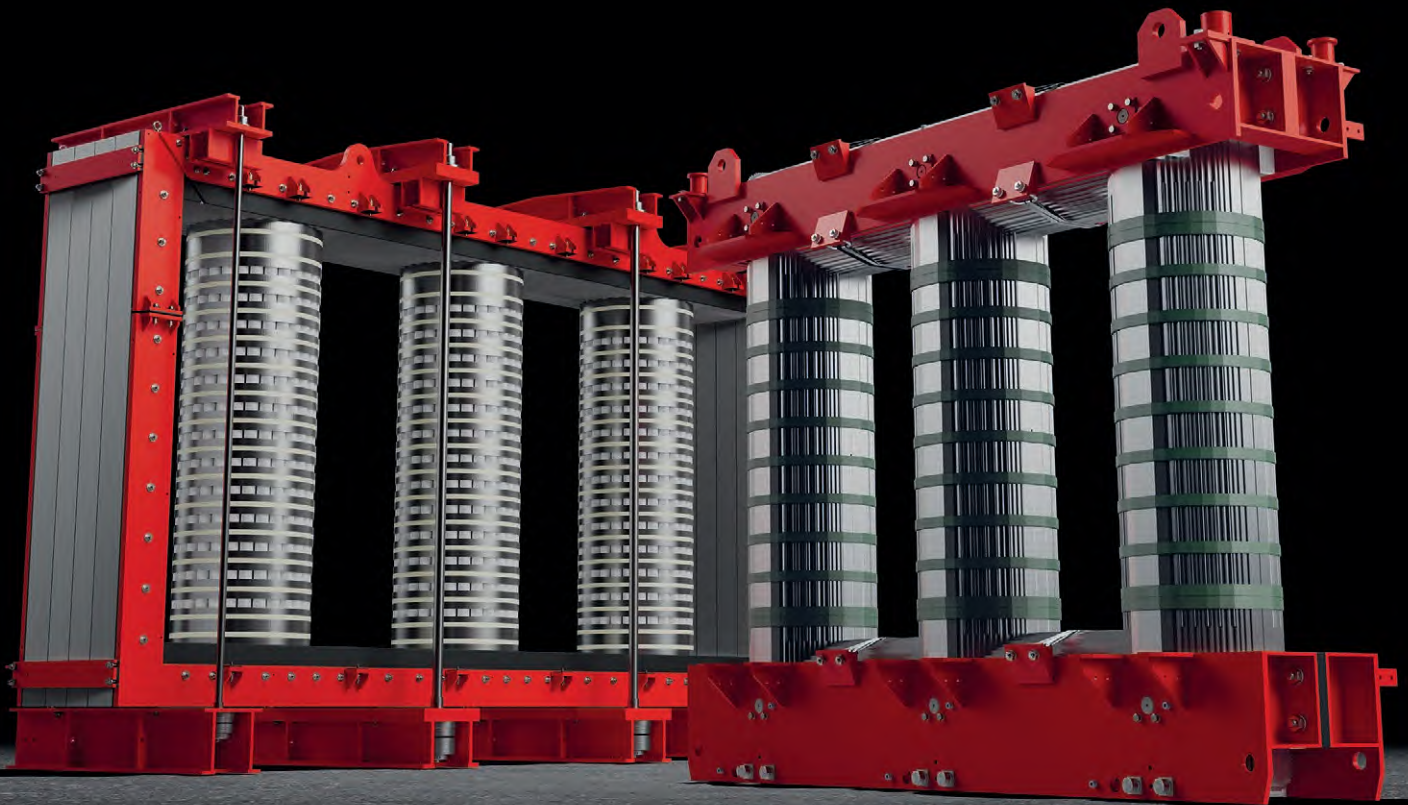
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Dear Readers,

Will the substations of tomorrow be simple mirrored pictures of the substations of old? Not very likely. Just as the Grid Edge and technology changes bring about changes in assets, the substation of tomorrow must adapt to all of these changes to create reliability and resilience, especially in light of security and weather event challenges.



Will the substations of tomorrow be simple mirrored pictures of the substations of old? Not very likely. Just as the Grid Edge and technology changes bring about changes in assets, the substation of tomorrow must adapt to all of these changes to create reliability and resilience, especially in light of security and weather event challenges.

As evidenced by the content we lined up for this issue, there is as much change taking place within new substation design as there is within any part of grid modernization. But we cannot simply upgrade the grid by making upgrades to the designs of new substations, we must also upgrade existing substations in ways we never required before. All of this brings great challenges to the substation engineer and to the utilities that rely on them.

Recently I read something from A.P. Meliopoulos, the Georgia Power Distinguished Professor of Electrical engineering at my alma mater, GA Tech, on the impact of inverters on the modern grid. A decade ago, we started discussing the kinds of changes we would need to make for the grid of the future and now that it is upon us, we are seeing first-hand the need for updating technology as Dr. Meliopoulos describes.



There is as much change taking place within new substation design as there is within any part of grid modernization.



But he is not alone in drawing attention to changes we must incorporate to create a more resilient, secure and reliable grid.

Finally, I have personally been concerned that our additional brand called Power Systems Technology and the even newer Green Energy Technology might be a distraction from the bread-and-butter Transformer Technology brand. But our community members' reactions and that of our Technical Advisory Board (TAB) has been nothing but positive and supportive. We are as committed to Transformer Technology as ever, but see the need for a more integrated approach to our members needs and wants. This issue is a perfect illustration of how that integrated approach will work in our digital publications.

Coming in September will be another issue of Women in Power Systems (WPS), our third, where we have curated some inspirational and enlightening featured women of note in our industry. Then in October we focus on Bushings & Components (LTCs, Gauges, Controllers). It is one of our annual favorite issues, and we have added new advances in other transformer components, like LTCs and controllers. Bushing technology is also adapting to new demands with new materials and manufacturing processes that the professional engineer must keep track of, so while much of the editorial space is spoken for, if you have an article, perspective or interview you would like to submit, please reach out to me at alan.ross@apc.media as soon as possible. We will be closing editorial content soon.

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Alan M Ross



It's time to build extra grid resilience into substation strategy

by **Sami Raitakoski**

+++++





As the switch to electrification across the world continues to grow, the US government is prioritizing grid resilience like never before. With nearly 70 percent of the nation's grid more than 25 years old, the White House is making historic investments that will strengthen the transmission and distribution grid to drive down energy costs, generate good-paying jobs, and help keep the lights on during increasingly extreme weather events.



Sami Raitakoski is the head of ABB's Global Product Group, Medium-Voltage Grid Components, within the Distribution Solutions division. Prior to that, he was responsible for leading and growing the Asia-Pacific region's market share in Singapore, Australia, New Zealand, Malaysia, Philippines, Thailand, Japan, Vietnam, Indonesia, South Korea and Taiwan. Sami started his career with ABB as a design engineer in 1999, and over the past 20 years has held numerous senior management roles across Europe and Asia. From 2009 to 2017, Sami was the Head of Global Marketing and Sales for one of ABB's largest business units, Medium Voltage Products, based in Zurich. Sami has a Bachelor of Science in Electrical Power Engineering from the renowned Vaasa Institute of Technology, Finland.



The Department of Energy estimate that outages alone cost the US economy \$70 billion annually and this is only set to worsen without modernizing and expanding the domestic power grid.

But it's not just about building bigger and better to resolve the issue of energy security and reliability. To operate in an ever changing and volatile environment, utilities should develop effective resilience strategies, with greater system flexibility, delivered through digital and emerging technologies.

Electric grids need to become more robust and allow a quicker response to outages through better use of fault detection, isolation and restoration. Additionally, monitoring systems that perform complex functions, such as asset management, can greatly reduce capital costs and provide optimal grid efficiency.

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To operate in an ever changing and volatile environment, utilities should develop effective resilience strategies, with greater system flexibility, delivered through digital and emerging technologies.

Substation hardening

Consequently, there needs to be a shift from traditional and often reactive crisis planning to more proactive resiliency planning – preparing the grid ahead of time to prevent a crisis – and this starts with substation hardening and improving the use of existing asset capacity through a predictive servicing approach.

There is an unheralded, but nimble and adaptable technology at the edge of the grid that allows for two-way communication between the power source and the user, and that can quickly respond to changes in the power system in real time. Enter the humble circuit breaker, which protects electrical systems from damage by interrupting and safely re-establishing a disrupted current flow. If a short circuit occurs, a breaker isolates the section of the network at risk within milliseconds – which is 10 times faster than the blink of an eye – to safeguard the energy flow.

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There is an unheralded, but nimble and adaptable technology at the edge of the grid that allows for two-way communication between the power source and the user, and that can quickly respond to changes in the power system in real time. Enter the humble circuit breaker, which protects electrical systems from damage by interrupting and safely re-establishing a disrupted current flow.

Aging infrastructure certainly makes the network more susceptible to outages and Entergy New Orleans is a great example of a company undertaking upgrades as part of a proactive retrofit plan





Photo: ABB

(including multiple circuit breaker replacements) to improve resilience. Improvements at its 300 MW Derbigny substation have brought a stronger and more reliable grid to the downtown area and are helping deliver more consistent energy supplies to nearly 10,000 customers in the Central Business District of New Orleans.

Magnetic actuation technology

Plus, in the case of primary MV substation applications there's magnetic actuation circuit breaker technology, which delivers an even safer alternative by lengthening the time period between maintenance cycles and eliminating the problems traditionally associated with complex spring charge mechanisms.

The magnetic actuator is that rare maintenance-free mechanism, because only one moving part makes for minimal wear and tear. This is pretty unique, as spring-based alternatives with open compartments expose technicians to the danger of mechanical components, plus multiple gears and chains require a lot of regular cleaning/lubrication and spare parts - and are far less reliable when it comes to maintaining critical power supply.

Additionally, it allows for monitoring of the operating mechanism prior to an operation - for an ultra-reliable solution. We have helped hundreds of utilities (including Oncor, the largest transmission and distribution electric utility in the state of Texas and the fifth largest utility company in the US) make tangible savings by increasing product reliability and decreasing operation and maintenance costs by improved breaker performance.

It's rigorously tested with built-in safety features and from a physical security perspective installed inside substations that are fenced, gated and locked, with only authorized personnel allowed access and who have gone undergone utility specific training.

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Strengthen grid resiliency

Digitalization of this substation circuit breaker is imminent and this will further strengthen grid resiliency because it will sit independently within the network and allow for even quicker and easier storm restoration (via remote access) and absolute minimum downtime.

Meanwhile, natural disasters caused by extreme weather, including flooding, heat and drought continue to affect energy security and impact millions of people and businesses each year, costing billions. In response to these challenges and to meet utility demand for power safety and reliability, there is a next generation extreme weather

resistant housing cabinet for the magnetically actuated dead tank breakers that secure medium-voltage primary substations.

The housing has been designed to the stringent NEMA 4 rating standards, offering unparalleled protection against even the most severe water and dust ingress – up to 65Gal/min from any direction. Featuring seamless roof-to-wall joints and external self-sealing bolts that prevent any gaps, the housing is completely secure and watertight. A new roof overhang also helps limit water exposure, plus the bushings-to-roof interface is secured by a superior aerospace-grade UV-resistant and more robust gasket.

+

Even better for Original Equipment Manufacturers (OEMs), a three-point latch and self-aligning hinges help ensure a smooth and uniform door fit, while the enhanced position indicator window design also repels excess water levels.





Even better for Original Equipment Manufacturers (OEMs), a three-point latch and self-aligning hinges help ensure a smooth and uniform door fit, while the enhanced position indicator window design also repels excess water levels. The footprints can even be reduced from 60 in. width down to 52 in. width, offering space and resource savings in some of the R-MAG ratings.

Increased protection for substation personnel

There's also an option for Internal Arc Resistant housing (tested as per IEEE C37.20.7, Type 2B, 0.5s) and this new enclosure ensures any fire and gases are expelled in a controlled manner in the event of an internal arc fault. This means increased protection for substation personnel on all sides of the equipment, much lower risk of failure and downtime, plus faster overall restoration of the system.

However, as increasing electrification pushes existing grid infrastructure to the edge, modern substations must continue to become smarter, more secure, and easier to manage to allow utilities to redefine how they approach fluctuating demand and imbalances.

+

As increasing electrification pushes existing grid infrastructure to the edge, modern substations must continue to become smarter, more secure, and easier to manage to allow utilities to redefine how they approach fluctuating demand and imbalances.

The primary equipment, such as circuit breakers, protection relays, busbars and switchgear, can employ new materials and construction – and advance through digitalization – but essentially stays the same. The evolution enabling a changing power grid perhaps comes more from the intelligent secondary equipment.

Centralized protection and control (CPC) is a digital and software-oriented solution, which brings scalability and flexibility by moving substation P&C from multiple bay level devices to a single central processing unit. It typically comprises managed Ethernet switches, a time synchronization clock and merging units to digitalize the analog information from instrument transformers/sensors and interact with each breaker/contactors being protected. A CPC system unlocks benefits that could not be achieved earlier using multifunctional protection relays.

Substation automation

With CPC, the flexibility and performance of the whole automation system increases substantially, allowing for new ways to manage substation automation. It offers convenient station-wide visibility, minimal engineering, and cost-efficient system management, which in turn delivers enhanced reliability, availability and flexibility, plus reduced overall life cycle costs.

A single device can handle the tasks of 30 protection relays – centralizing this functionality in the substation reduces network complexity - while also carrying out real-time monitoring and control of distributed energy resources.

What's more, the first ever virtualized CPC has just been launched to help substation owners maximize asset utilization. They can further enhance automation by simply installing standalone software on the hardware of their choice to optimize their IT infrastructure. This approach means operators can have multiple CPC instances on a single computer for even bigger systems.



With virtualized functionality, a substation owner can also replace different kinds of old equipment with the same type of new equipment. This considerably reduces the amount of knowledge required to maintain the substation because of the smaller amount of hardware variants.

Optimizing assets

Utilities are facing an unprecedented pressure to ensure grid resiliency today while also preparing for the environmental challenges of tomorrow. Substation strategy must electrify the grid with more resiliency against extreme weather and include optimizing assets, because the most sustainable and cost-effective solution is assessing existing equipment.

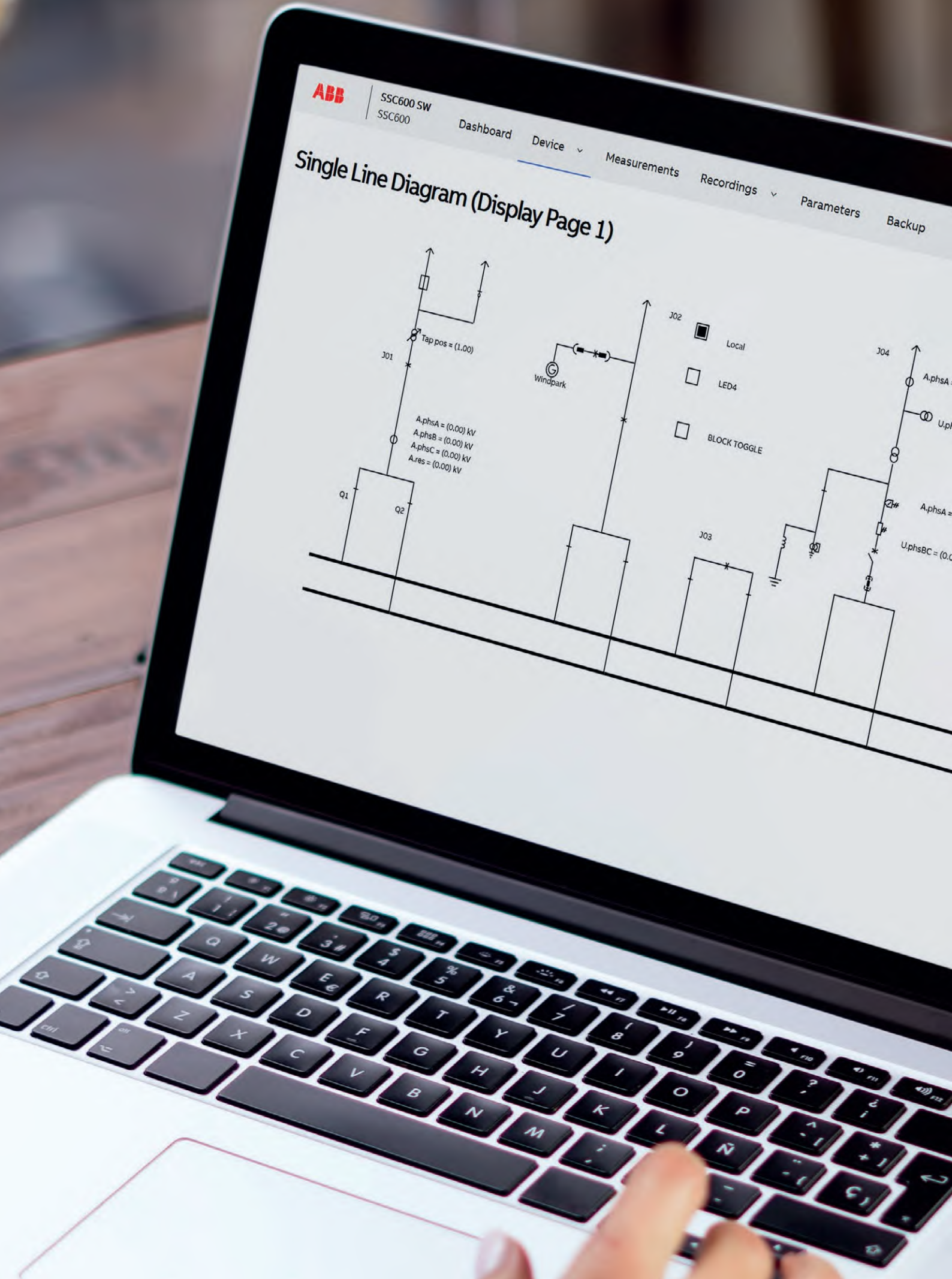
Smarter and well-planned investment will improve distribution security, while it's also a case of achieving much more with much less, while continuing to use the existing and limited power grid infrastructure and simultaneously transitioning to a new one.

However, by also leveraging new technologies, such as the industry's very first virtualised protection and control solution for substations, utilities can achieve improved grid stability with greater ease and speed.

+

Smarter and well-planned investment will improve distribution security, while it's also a case of achieving much more with much less, while continuing to use the existing and limited power grid infrastructure and simultaneously transitioning to a new one.





SSC600 SW
SSC600

Dashboard

Device

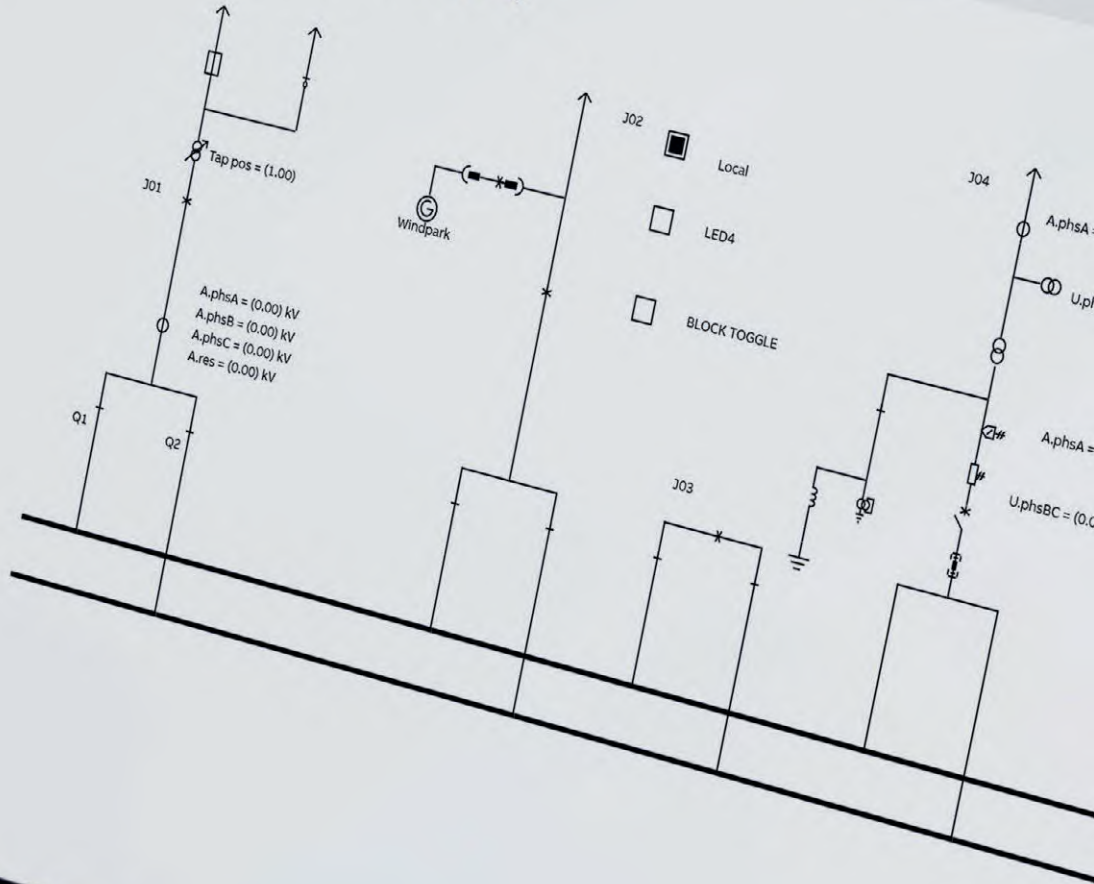
Measurements

Recordings

Parameters

Backup

Single Line Diagram (Display Page 1)



J01

Tap pos = (1.00)
A.phsA = (0.00) kV
A.phsB = (0.00) kV
A.phsC = (0.00) kV
A.res = (0.00) kV

Q1

Q2

Windpark

J02

Local

LED4

BLOCK TOGGLE

J04

A.phsA =

U.phsBC = (0.00) kV

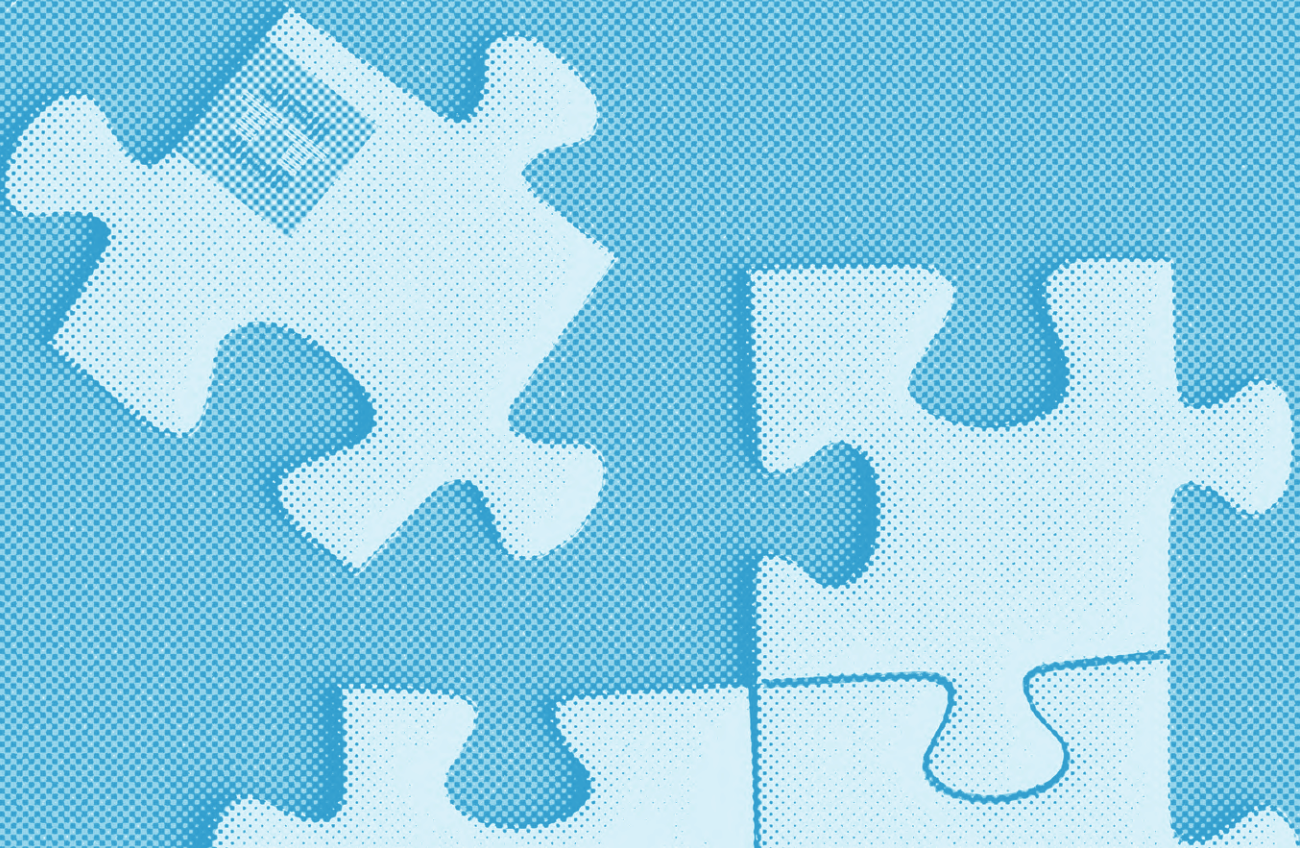
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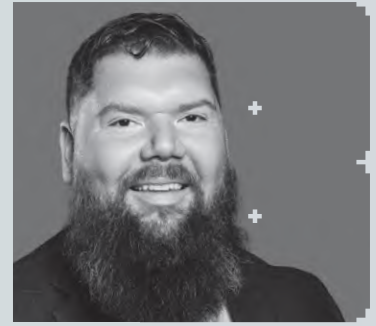
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The majority of these defects are caused by poor workmanship during cable or termination installation, but other factors include manufacturing errors, electrical stress, thermal stress, or environmental factors. The location of these defects can be determined during the measurement process.



Jason Aaron, a Marine Corps veteran, has worked in the power industry for over 15 years as a field technician and applications engineer. He currently holds the position of Cable Infrastructure Program Manager for North America at Megger. Previously Jason has performed start-up, maintenance and commissioning of electrical power systems and substations while earning a Level IV NETA certification. He is a member of the IEEE Power & Energy Society, a voting member of the IEEE standards society, actively involved with a working group for IEEE 400.2 and an IEEE C37.14 task force for DC circuit breaker traction power applications. In his current role, Jason primarily focuses on the areas of power cable testing, diagnostics, and fault location techniques with emphasis on power system reliability, asset management and proper diagnostic test procedures.



Joseph Aguirre, a highly skilled Application Engineer at Megger. With expertise in cable testing, diagnostic and fault location techniques, as well as testing of all substation apparatuses. He has a passion for training end-users on the proper use and theory of various pieces of high-voltage testing equipment. Joseph holds a B.S. in Industrial Technology from the University of Texas of the Permian Basin and is currently pursuing two graduate degrees in Energy Finance and MBA. Before joining Megger, he has worked in various roles such as a maintenance technician, a crew foreman for a utility in substation maintenance/construction, and as a NETA testing technician providing commissioning and maintenance on all substation apparatus and industrial electrical equipment. With his vast experience and knowledge, Joseph is continuously making innovative contributions to the field of cable testing and substation maintenance.



lasting less than 1 microsecond. These voltages or current pulses can be measured and recorded. The quantity for this measurement is referred to as the apparent charge. The system used to perform this measurement typically consists of a voltage source, a coupling device, and a measurement instrument. The coupling device typically includes a coupling capacitor to measure impedance and a PD detector for amplifying, filtering, and processing the decoupled PD signals.

In power cables, partial discharge is generally a result of ionizable, gas-filled voids created by defects in the insulation. The majority of these defects are caused by poor workmanship during cable or termination installation, but other

factors include manufacturing errors, electrical stress, thermal stress, or environmental factors. The location of these defects can be determined during the measurement process.

The high-frequency pulses in cables propagate in both directions allowing the measurement system to calculate the position of the partial discharges. (Figure 2.)

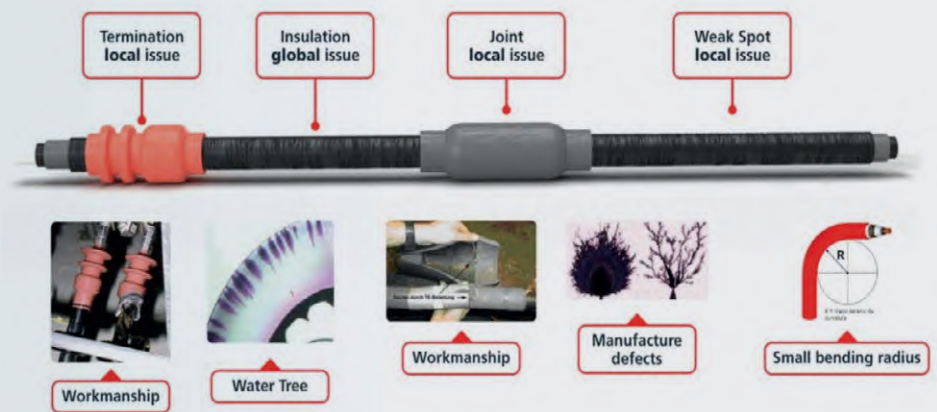


Figure 1: Types of defects in power cables.

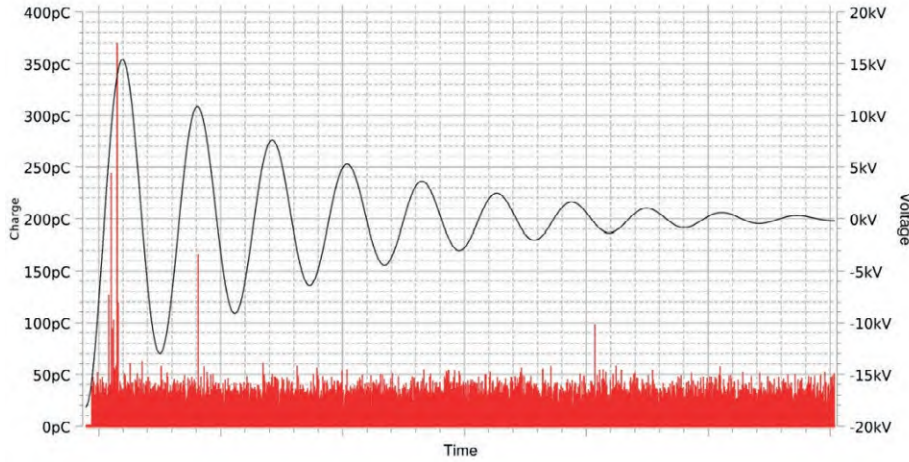


Figure 5: Typical Damped AC Voltage

This is accomplished through partial discharge mapping using the instrument software (Figure 5).

PDIV/PDEV

The PDIV/PDEV relative to the rated voltage of the cable (U_0) is another characteristic to evaluate. Generally, PDIV values exceeding 1.7 times the voltage rating of the cable is acceptable. This establishes the voltage magnitude where PD would initiate and answers the question of; if PD activity is present. PDIV found at or near the 1.0 times U_0 is a cause for alarm, and a deeper investigation is required. If partial discharge activity is not present, this is considered to be a successful test. In the instance that PDIV is discovered, PDEV is then established. There are different sets of criteria depending on what is being evaluated in the cable system.

For the cable itself, any detection of partial discharge is a concern

and should be followed with further investigation. Although, PDEV should be measured to determine the severity of the deterioration for making decisions involving the cable in question. For cable accessories, such as splices and terminations, there are acceptable tolerances for PDEV. The localization ability allows for the determination of the specific source of PD to identify whether it is an accessory. In these cases, each type of accessory has different criteria. The minimum acceptable PDEV is 1.5 U_0 for cable joints (IEEE 404) [2] and terminations (IEEE 48) [3], while separable connectors (IEEE 386) [4] are 1.3 U_0 . For cases where cable accessories fail to meet the minimum PDEV values, the severity of the activity and criticality of the circuit should be taken into consideration for cable maintenance decisions. Additionally, other diagnostic methods and testing may be necessary.

Discharge Magnitude

The coulomb is used for the measurement of PD activity. Generally, on the scale of Pico coulombs (10⁻¹²) or Nano coulombs (10⁻⁹). For PD testing, any measurement above 5 pC is above acceptable thresholds for lab testing. However, this value was established for lab environments on new cable systems. Measurements in the field have other aspects to consider, such as background noise, grounding conditions, and the age of the cable, as previously mentioned. Therefore, the background noise value must be considered when grading the quality of a cable exhibiting low levels of PD activity. For example, if the noise floor measurement was 50 pC, a measurement beginning at 60 or 70 pC should be noted and recorded. Decisions can be made for appropriate follow-up actions based on the PDIV and PDEV values in relation to established tolerances (seen above) and whether it is a critical circuit to operations.

PRPD, phase-resolved partial discharge

The type of discharge should be determined based on the PRPD pattern. PRPD has been previously discussed in this paper and can be applied as a useful tool for determining if PD being detected is a concern. In some cases, it may be corona discharges created by a poor test setup. This can be alleviated by adjusting the setup and retesting. In other cases, surface and/or void discharges are produced internally

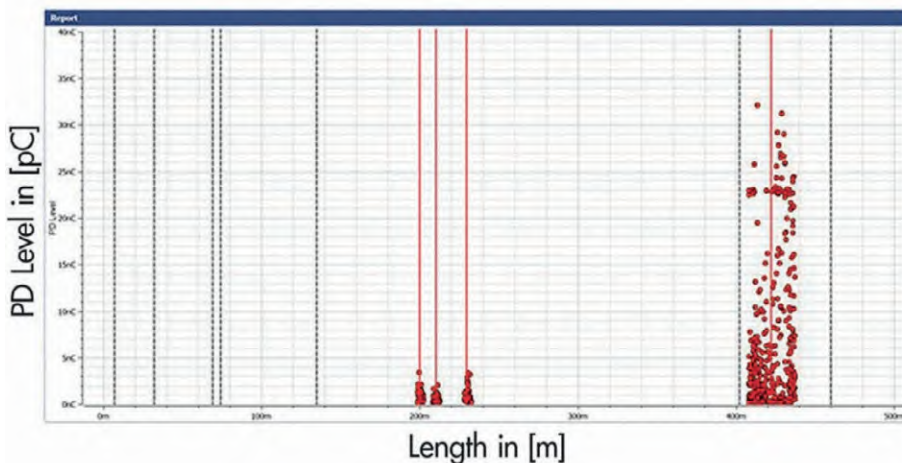


Figure 6. Partial Discharge Mapping

A particularly useful technique in PD diagnostic is Damped AC (DAC). DAC utilizes a resonance circuit, similar to Cosine Rectangular (CR), that allows voltages to decay exponentially through resistive losses in the circuit.

The applications of CR and DAC are comparable to power frequency power sources. This is due to the gradient of the applied voltage, which is the rate of change in the applied voltage with respect to time.

with serious defects that will need to be addressed with further testing and investigation of the cable defects. Identification of the types of PD being measured can help avoid lost downtime due to the investigation of a phantom defect caused by an inadequate test setup. On the other hand, it can also validate the presence of PD activity needing immediate attention.

Conclusion

Partial discharge (PD) diagnosis of medium voltage power cables is essential in the successful and safe operation of any modern energy system. PD testing enables engineers to detect defects in power cables before they become dangerous or cause irreparable damage, safeguarding both people and components. Through PD diagnosis, engineers can also accurately measure leakage levels, allowing them to identify elements that may fail without sacrificing the cable's integrity.

PD testing involves applying varying waveforms and voltages on power cables, which detect any irregular behavior of the cable's insulation system that may indicate the presence of a fault. PD provides engineers with the essential information required to ensure the efficiency of modern energy systems. As such, it can serve as a cost-effective alternative to replacement or repair

through its ability to address issues quickly and safely. All with minimal disruption or downtime for the energy system. In addition to providing an effective means of detecting faults, PD diagnosis plays a crucial role in catching potential problems before they escalate and become more hazardous or damaging. PD diagnosis is also invaluable for predicting future cable performance and getting the maximum life out of medium-voltage power cables.

To conclude, PD Diagnosis serves various purposes that justify its implementation into energy systems, from cable-related issues to improving overall reliability and longevity by identifying potentially faulty cable sections. Also, amongst other equipment where predetermined electrical tolerances are not met. Partial discharge should rightly be considered integral to commission and maintenance test procedures when dealing with medium-voltage power cables.

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- [2] "IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5 kV to 500 kV," in IEEE Std 404-2022, vol., no., pp.1-46, 21 March 2023, doi: 10.1109/IEEESTD.2023.10077511.
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Jason Neal

President of Hyosung HICO and
Senior Executive Vice President of HICO America

Interview with **Jason Neal**

“

Sustainability is important to our company, to the industry, and the world. The growth of renewable energy and renewable sources of generation, like wind and solar, is extremely important; to the growth of electric vehicles and the infrastructure to support them, that's important as well. It means a great opportunity, but also great challenges.

HICO AMERICA

HYOSUNG HEAVY INDUSTRIES CORPORATION



Alan Ross: I'm Alan Ross. I'm the Managing Editor of Power Systems Technology and Transformer Technology. My guest today is Jason Neal.

Jason, what are your titles at HICO?

Jason Neal: President of Hyosung HICO and Senior Executive Vice President of HICO America.

AR Tell me about your background, your career, and your trajectory.

JN I'm an electrical engineer by education. I worked with a few other companies in the industry and had the great fortune of joining HICO when we started our business here in the US in September of 2001. I've been here ever since in different roles.

AR Let's talk about one of the things you and I had a conversation about before - sustainability of power systems. Describe what that means when you say sustainability of power systems.

JN Sustainability is important to our company, it's important to the industry and the world. The growth of renewable energy and renewable sources of generation, like wind and solar, is extremely important; to the growth of electric vehicles and the infrastructure to support them, that's important as well. It means a great opportunity, but also great challenges. Utilities and the market are facing unprecedented challenges. Renewable energy is excellent, but to incorporate those resources we have to balance the power system, frequency issues, voltage issues, developing solutions around that; suppliers need to be attentive to the market and the industry needs to bring solutions that can enable more wind, more solar to be installed here in the States.

AR The word "sustainable" typically means we are using products or doing something which helps save the Earth. When you talk about sustainability of power systems, you're really talking about sustainability of the power grid for our economy, right?

JN Yes. Sustainable energy sources, resiliency of the grid itself and the solutions that are to support the incorporation of any generation source, be that something that's renewable or sustainable or generation sources that are here already in the market. It's more than just green energy. It's a resilient, stable power grid with stable supply bases, stable sources of generation as well.

AR We have a situation that whether it's the hot summer or the cold

winter, ERCOT, the Texas grid, is tending to have problems that they never had before. We're in a situation where there is extreme heat. Everybody's running air conditioning. In fact, you couldn't live in Houston if there was no air conditioning. So the idea is that power is so critical and important. Then we tell everybody it's not just power utilities anymore. You now have to worry about green energy. Talk a little bit about your idea of how green energy, storage, wind, and solar all plays into this resiliency of the grid, especially when it comes to battery storage.

JN There's a lot of applications for battery storage, certainly the classic use-case of integrating renewable sources of energy, like wind and solar. That's a great opportunity. There are challenges with that in and of itself. You can't be focused on just one technology. That battery choice is important; looking ahead to new battery technologies like flow batteries, long duration batteries, certainly there are challenges there. Even selection of things like inverters - either inverters that could be grid-following, or inverters that could be grid-forming, and having islanding capabilities. The classic application for storage is really aligned with green energy, but there are other applications as well. You can think about battery storage as having the potential to bring stability to the power system. All the inverter-based generation, STATCOM, synchronous condensers, they all have a place, but so does battery storage. It's selecting that inverter that's quick responding to being called upon and injecting that power, that can be a way to regulate frequency.

The classic application for storage is really aligned with green energy, but there are other applications as well. You can think about battery storage as having the potential to bring stability to the power system.

AR California has a lot of solar and wind, but the inverter-based system is aging the distribution transformers much faster than they had planned for. Because we're in a step-down world, suddenly we're step everywhere. Talk a little bit about that, because you mentioned inverters, but what does that do to the sustainability of the existing grid?

JN Whether it's these distribution transformers that are directly

connected, or transformers that are elsewhere on the system, the new harmonics that are on the system and the need to consider equipment that may not have been designed for that; it's not just that installation itself, it's the transmission system. It's the impact on the transmission system and it's the distribution of that power to the end user and all the equipment that's down the line that has to be considered, including, as you say, distribution transformers. As well as all these solutions are coming about with STATCOMs and synchronous condensers to balance that out.

changed at 0.5 % per year to a utility specifying 0.1 % per year, suppliers have to step up to address that. But it's also, as you said, developing new technology using non-SF6 solutions. So if it's things like we're doing with our medium voltage gear, being the first company to market with a zero global warming potential gas for our medium voltage gear to the installed base that we have with our non SF6 high voltage GIS, it's a combination. We saw with state of New York, I think it was last month, following what's going on in California and Massachusetts on these requirements for eliminating SF6.



AR With 22 years under your belt, it is a good time to be where you are because you know what great change brings? Opportunity. Everything you've described is it's all a lot going on, but it's all opportunity. One of the things that's changing that I want to talk a little bit about, what's going on in your mind with how are we replacing SF6, both from the standpoint of the gas itself and the standpoint of the equipment? How are we handling that change or how is your company handling it?

JN There's a lot of ways to look at it. First is looking at the existing SF6 equipment that's being delivered now and managing the emission of SF6, reducing the leak rates of this equipment. If it's the IEEE standard being

And it's managing the emissions, it's pushing the development of new technology and non-SF6 technology, and making sure to address cases where there may not be technology available and how to handle that. But it's a very important development.

AR Another change that's coming that's going to bring opportunity for those people that can adapt. It's driving some of the utilities nuts, but guess what? That's what we're supposed to - drive them to the new solutions.

Right now, we have a shortage of transformers. It doesn't matter what class of transformer you're trying to get. It's hard to do it. Then you have the government saying they want to go

Photo: HICO America

to amorphous steel and get away from grain-oriented steel. However, we've got 25 % tariffs on grain. We're doing everything that we can to make it harder to make transformers. And yet we have a transformer shortage. What's your experience with that right now?

JN Looking at it long term, demand is far exceeding supply. All these things we've spoken about, the growth of renewables, the growth and the infrastructure development to incorporate EVs, big data. Utilities are facing challenges like never before, unprecedented. As a supplier, there's a few things that the companies could be doing. One is definitely attacking the supply chain. Since COVID, since the war in Ukraine, there's been certainly more of a focus and more visibility in the supply chain, onshoring suppliers, near-shoring suppliers, and making sure the relationships with suppliers are strong, because now is the time where suppliers have to step up and perform. I think it's attracting talent to our industry, training people and retaining them so we can build more. Now we are the cool industry. I think the industry is doing a solid job of selling the future of power. You look at all the developments that are going on right now with EVs, with new battery technologies, with hydrogen, power electronics, statcoms, HVDC. We're the cool industry to work for. We need to keep selling that to attract people so that we could do more as suppliers.

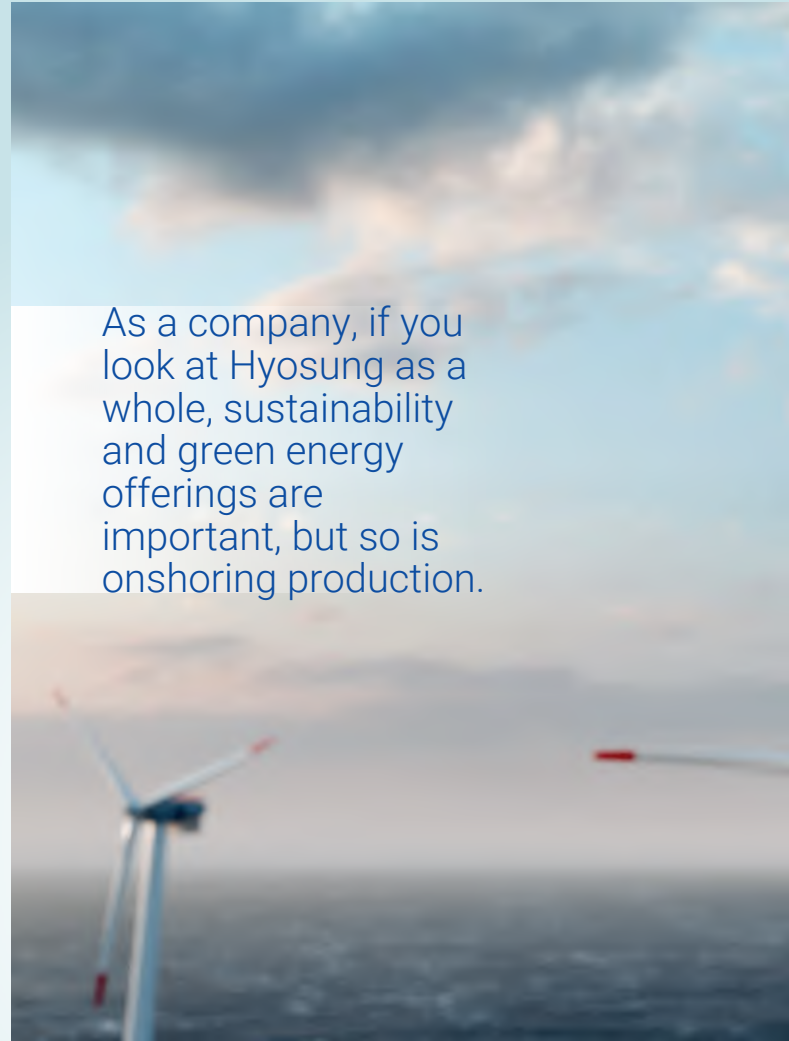
Utilities are facing challenges like never before, unprecedented. As a supplier, there's a few things that the companies could be doing. One is definitely attacking the supply chain.

AR We had a meeting this morning talking about an issue that we're going to be doing, our issue on women in power systems. Now you're getting more and more women. There are more women in EE programs in the United States than ever before, which is great. That's beyond STEM, right? I think it's because we're the cool industry. I'm going to get a T shirt that says now I'm cool.

JN Listen, there's great opportunity. My father worked for a local utility here for 38 years. When I came out of school, I'll be honest, the last thing I wanted to do was get into

utilities. It wasn't the exciting industry at the time right? Back then it was semiconductors. It was process control. But if you look at it and the folks that we're bringing on board and why they're staying, it's exciting. It's a great time for the industry.

AR Let's talk now specifically about HICO America and Hyosung. In the marketplace, people say, it's the big three, big four. It's GE Vernova, Siemens, Hitachi, which was Hitachi, and then ABB, now it's Hitachi ABB.



As a company, if you look at Hyosung as a whole, sustainability and green energy offerings are important, but so is onshoring production.

From the mindset standpoint, HICO Hyosung, and especially HICO Americas, you're not a new entrant into the market, but you're a large entrant into the market. Talk a little bit about where you see the future for HICO America. What's your go to market strategy?

JN We've been here, like I mentioned, since September of '01. Our initial focus was power transformers. As a company, if you look at Hyosung as a whole, sustainability and green energy offerings are important, but so is onshoring production. On the transformer side of our business, establishing that factory in Memphis was a dream for me, for all of us that have been with HICO for a long time.

We are increasing our ability to ramp up Memphis to address the new demand from the market, which is far exceeding supply. But the other lines of our business are growing just as quickly. We are offering STATCOM, Battery Storage, HV and MV GIS as well as services around these solutions. So no longer are we just building a high-voltage or a medium-voltage gas insulated switchgear and substations. We're also expanding our business to be able to serve and maintain that substation for 5, 10, 15 plus years.

nice blend of folks that have been in this industry with experience, folks that have come from other industries. When you're maintaining some of these installations, the HVAC and pumps and coolers are just as important as the equipment itself. So that blend of people with experience in those areas is important. Then, bringing that next generation of maintenance persons, technicians, or engineers on board to learn from those folks, to get hands on experience side by side, and then to continue to grow how they work here and become the next generation of trainers, so to speak.



AR The Department of Labor estimates that every year between 2020 and 2030, we're going to lose 5 % of the current labor force. Plus, we're going to need 13 % more than we currently have. So you have a net negative of 18 % a year annualized. I want to talk about your philosophy for how do you recruit, train, promote, and inspire those people that are out in the field doing the kinds of maintenance, the kinds of work that you need them to do.

JN A big part is the training. There's a lot of experience here in the market. There's a lot of great folks working with suppliers and customers all across the market. They need to impart that wisdom and experience. We've built a

AR The other thing that you mentioned was, for any of your customers, you can either componentize, you can sell them a transformer, install a transformer, you can work with their GIS system, all that, or you can do it all, it seems like, which is a concept that I think a lot of, especially the smaller utilities are looking for. Is that the strategy that you're trying to present to them?

JN It is. It's important to adapt to what solution the customer needs. If it's a component-based project or product-based project, or if it's a full turnkey, soup-to-nuts, plus maintaining it for future years. And there are large utilities, large developers as well as smaller

companies that need that service. But it's really being attentive and being able to adapt. But that really is the industry. I think that's where the growth is. And certainly for HICO, that's where our growth is as well. Having that flexibility, listening to the voice of the customer always will be our guide and lead us into the right aspects of the market.

AR Back in the 1980s and 90s, we use the word full solution, whereas Solutions Company, everybody put on their website Solutions Company, meaning the customer would come to us and whatever they needed, we would provide them with the solution. But a complex solution requires complex thinking. It requires a different level of consultative engineering doing. My assumption is that you've built that and are continuing to build that, which is different than the installation and maintenance people. This is now the brainiacs that are saying, this is what you need, Mr. Utility, for the future. Is that a fair statement?

JN Very fair. And you need that feedback loop as well. So the folks that are working on these projects in a certain application, getting that feedback to our R&D folks. We're continuing to develop the solutions that the market needs. Therefore, adaptability and the flexibility to tailor what we're doing to the customer is important. But that feedback loop of the experience from that project, leading to the next generation of batteries or statcom valves, non SF6 gas technology is also another aspect of this.

AR I'm glad that you've got the Memphis facility. I live in Atlanta, so we're about five hours apart and I want to come and visit you. I was there when that facility first really came online years ago. Congratulations because you bought that facility from somebody, right?

JN We did. Initially, we announced, it's probably five years ago now, that we would build a new transformer facility in the US, then the facility in Memphis became available. And it's a beautiful facility. Great equipment, great people that were there. And it's been a great success story for us from the beginning. We opened Valentine's Day at 2020 and shipped our first transformer in June of that year, despite COVID and all the other challenges. We hit the ground running and we haven't stopped since.

AR There's a lot of change going on and some of it negative. I mean, we've got a lot of pushback from people that are saying, hey, you're moving too fast.

Wind and solar cannot sustain this, we don't have a sustainable EV market. These problems can be insurmountable if you look at them in the macro. When you look at them, what do you see?

JN It's really an opportunity. Our utility partners need time to focus and be




forward thinking on these. Now more than ever, suppliers have to perform well. A utility should not be worrying about how supplier X, Y, or Z is going to be performing on a specific project. We're responsible to make sure we're performing well so utilities can continue to be more forward-thinking. But that partnership between the utility and the

supplier, with our tier one and tier two suppliers to make sure not only are we performing, but we're developing the technologies, we're responsibly ramping up production to support the demand, to support the utilities and developers and all these challenges they're facing is more important now than ever.



We're continuing to develop the solutions that the market needs. Therefore, adaptability and the flexibility to tailor what we're doing to the customer is important.





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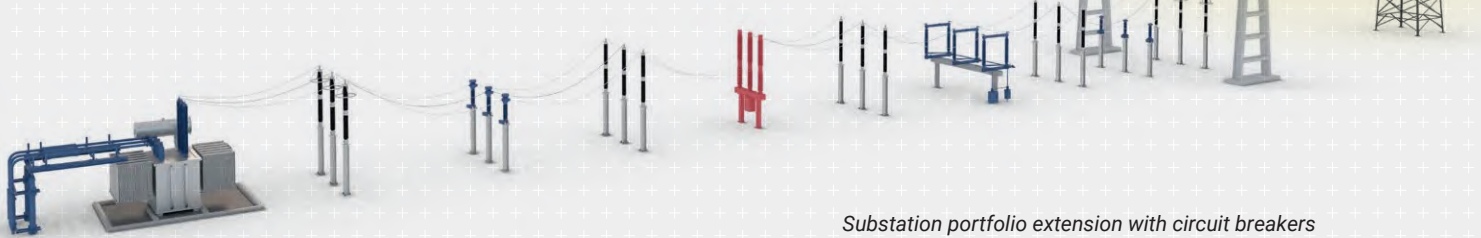
Collaborating to Address the Challenges of a Sustainable and Environmentally-Friendly

The need for clean electricity is rising rapidly, and so is the importance of ensuring the safety and reliability of the power grid.

Power Systems Future

It is clear that the shift toward sustainable power generation is unavoidable.

The need for clean electricity is rising rapidly, and so is the importance of ensuring the safety and reliability of the power grid.



Substation portfolio extension with circuit breakers



SF6-gas-free instrument transformers for AIS applications

Transforming the grid - Innovative technologies requested

The commitment of many stakeholders to reduce CO₂ emissions is triggering many changes in the power T&D sector. E-mobility and heat pumps as replacements for oil & gas driven mobility and heating systems are requesting a higher demand for electrical power. Large bulk power from offshore renewables must be transferred via DC systems. Regulations in different countries call for replacing the extremely good insulation gas SF₆. Fluctuating power generation from solar and wind power plants challenges the grid. It demands long-term and short-term energy storage solutions and grid control inventions on the system control level.

In addition, the electrical infrastructure is reaching end-of-life and requesting replacement after 35-40 years in service. The call for fewer power losses in our electrical grid is triggering the application of new technologies, which shall be competitive to keep the energy cost at an acceptable level. Both investment streams in new and existing infrastructure are stressing the whole ecosystem of our T&D industry and grid owners/operators. These are fascinating times for all people along the value-added chain of our T&D segment.

Our PFIFFNER Group is well-positioned in this sector and has heavily invested in developing products and solutions to cope with the demand of our customers. Our brand PFIFFNER has launched the first series of SF₆-gas-free instrument transformers for AIS applications. In addition, an F-gas-free life-tank circuit breaker is in the development stage and will be 2025 available on the market. This shall help our customers massively reduce their CO₂ footprint and eliminate the efforts to report an SF₆ balance.

Our brand PFIFFNER has launched the first series of SF₆-gas-free instrument transformers for AIS applications. In addition, an F-gas-free life-tank circuit breaker is in the development stage and will be 2025 available on the market.

Offshore platforms are costly, and therefore weight and space are constraints. Resin-impregnated busbar solutions from our brand, MOSER GLASER, instead of cables, shall help our customers to overcome these constraints. The market demand for this solution is proving that this concept has a value-add for our customers.

Low losses characterize an efficient grid. All grid elements shall function with low electrical losses. Highly accurate transformer loss measuring systems from our brand HAEFELY shall prove the efficiency of transformers. With extremely short measuring time and high reliability, we guarantee a short throughput time in transformer factories.

Retrofit solutions like our new center breaker disconnecting earthing switch fully type tested in the voltage range of 72 – 420 kV from our brand ALPHA-ET or the new DC current transformer from PFIFFNER for HVDC, traction or AC grids to measure the DC content complement our offering to our customers to support the transition of the electrical grid.

Offshore platforms are costly, and therefore weight and space are constraints. Resin-impregnated busbar solutions from our brand, MOSER GLASER, instead of cables, shall help our customers to overcome these constraints.

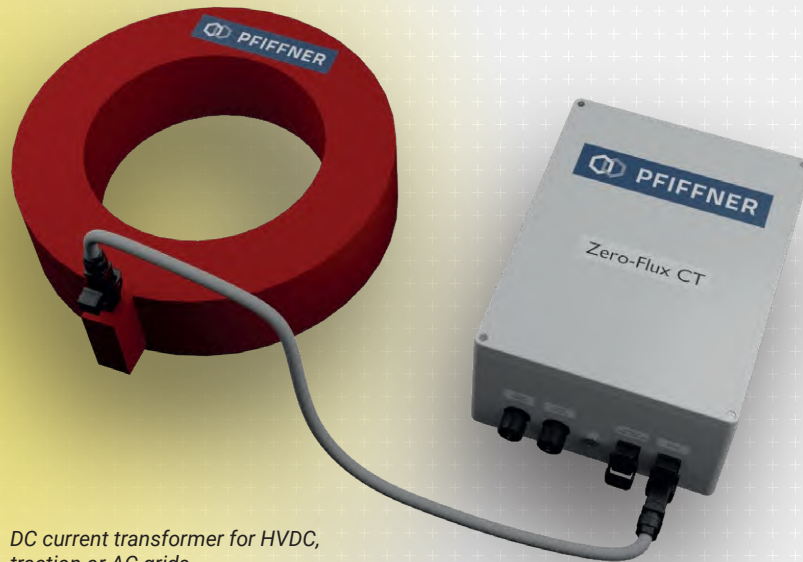
We have to act fast: starting initiatives like supporting the high-voltage faculties of universities, going to schools and attracting apprentices who can later perform the service jobs in substations or organize trade events to network and share knowledge.

Transforming the grid – calling for people to join our sector

Our T&D sector has lost its attractiveness in recent years while others gained. It is visible in the low number of students in our power systems sector and the substantial number of open positions. The root causes are our conservative and less innovative business environment and our habit of doing good things, but not talking about them. We have to change our image to overcome the situation. Therefore, we act fast: starting initiatives like supporting the high-voltage faculties of universities, going to schools and attracting apprentices who can later perform service jobs in substations, or organizing trade events to network and share knowledge.



DURESCA® offshore busbars



DC current transformer for HVDC, traction or AC grids

Join us for the Swiss T&D Days organized by the Pfiffner Group, where we will address the challenges facing the electrical transmission and distribution grids today and in the future.

Swiss T&D Days 2023: Come Together – Go Further

Join us for the Swiss T&D Days organized by the Pfiffner Group, where we will address the challenges facing the electrical transmission and distribution grids today and in the future. This event is the perfect platform for exchanging ideas and discussing current affairs with renowned utilities, universities, and leading companies in the T&D sector. Take advantage of this significant gathering of industry experts and secure your place by registering to attend on October 17 and 18, 2023. For more information and registration, visit [swiss-td-days.ch](https://www.swiss-td-days.ch).

PFIFFNER International is a medium-sized, family-owned group of companies headquartered in Hirschthal, Switzerland. We develop, produce and distribute products and solutions for customers in the transmission & distribution (T&D) and rolling stock sector. We have been present on the market for many decades with the brands PFIFFNER, MOSER GLASER, HAEFELY, ALPHA-ET, HAVECO, and PFIFFNER Systems.

PFIFFNER International has around 900 employees, generating a turnover of approx. CHF 170 million has eight production sites in Switzerland, Germany, Turkey, Brazil, and India and pursues about two service providers.

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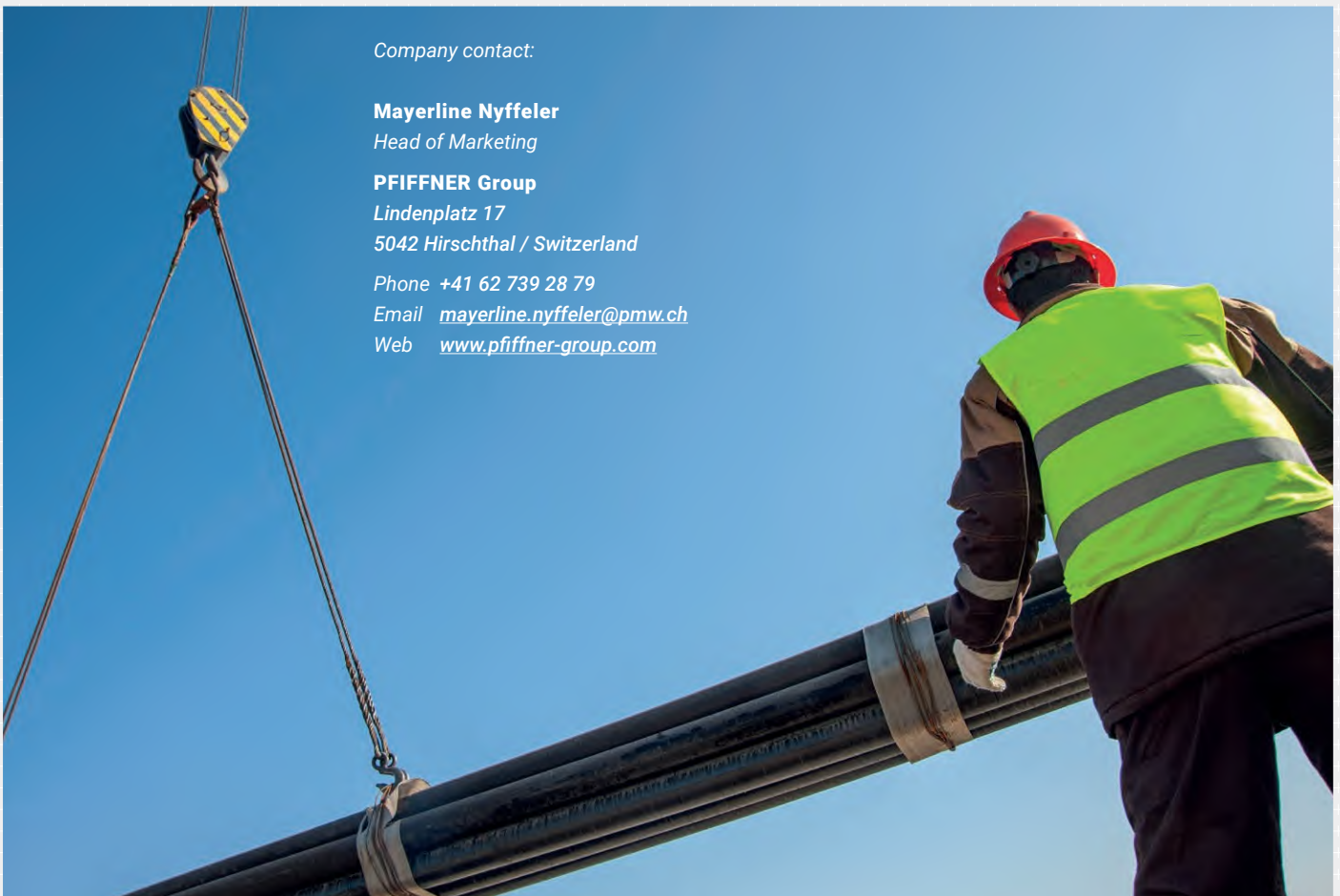
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Protecting your ASSETS

by **Brad Nanna**
+++++

The primary goal of NFPA 70B is to reduce the risk of electrical hazards, and electrical shock, by promoting effective maintenance practices for electrical systems, equipment, and components.



For over 30 years, **Brad Nanna** has been in the Electrical Power Industry promoting solutions and service to customers in the residential, commercial, industrial and utilities markets. His experiences include knowledge and specification influence in electrical power distribution equipment, switchgear, transformers, industrial and motor control. He has held positions in Sales, Marketing, Product Management with primary focus on electrical preventative maintenance (EPM) and electrical safety standards of NFPA and OSHA. Brad is currently employed by IRISS and leading their efforts in inspection Infrared (IR) Thermography and Ultrasound testing. He is also leading the efforts of an electrical Operations Driven Safety and Reliability program (ODSR) for a safer, most reliable electrical asset management system. Brad holds an MBA from Clemson University and a BS degree in electrical engineering from the University of Pittsburgh. He is a member of IEEE, enjoys working with local universities in the development of engineering, sales and marketing classes, and a seasoned speaker on electrical safety and reliability.

NFPA 70B is a standard published by the National Fire Protection Association (NFPA) that provides guidelines for electrical equipment maintenance and testing. It focuses on establishing practices for the proper care and maintenance of electrical systems and equipment to ensure reliable and safe operation.

The primary goal of NFPA 70B is to reduce the risk of electrical hazards, and electrical shock, by promoting effective maintenance practices for electrical systems, equipment, and components.

The standard covers a wide range of electrical equipment, including power

generation systems, transformers, switchgear, motor control centers, motors, batteries, lighting systems, and more. NFPA 70B introduces the concept of maintenance categories, which are used to determine the appropriate maintenance and testing activities for different types of electrical equipment.



The categories include:

1. **Emergency Maintenance:** Immediate repair or replacement of failed equipment to prevent harm or further damage.
2. **Corrective Maintenance:** Repairing or replacing failed equipment or components after they have been identified as faulty through inspection or testing.
3. **Preventive Maintenance:** Planned maintenance activities conducted at predetermined intervals to prevent equipment failure.
4. **Predictive Maintenance:** Using diagnostic techniques to monitor equipment's condition and predict when maintenance is required.

The standard emphasizes the importance of following manufacturer recommendations and industry best practices for inspection and testing to identify and avoid potential issues or deterioration. It covers visual inspections, thermography, voltage and current measurements, and other testing techniques.

New to the standard as a requirement, but not to the industry, is Thermography testing of electrical connections and terminations. Thermography testing, also known as infrared (IR) thermography or thermal imaging, is a non-destructive testing method that uses infrared cameras to detect and visualize temperature variations in an object or system.

It measures the thermal energy emitted by an object and creates a visual representation called a thermogram or thermal image. Different objects and materials emit thermal energy at varying rates. Thermography testing measures temperature variations and creates a visual representation of heat patterns on the surface of the object or system being inspected.

In order to perform Thermography testing safely, consideration of using inspection Infrared (IR) windows is an absolute must. IR windows protect operators from uncovered and dangerous high currents. They provide a safe and convenient method to conduct thermography

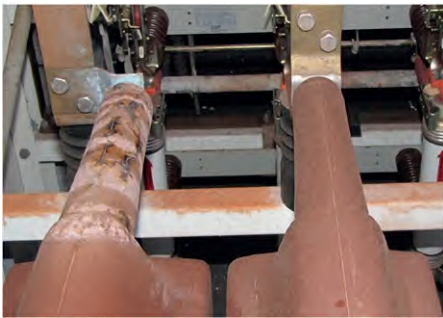
testing on energized electrical systems without the need to remove covers or panels.

Not only do IR windows provide added safety to inspectors from live "hot" circuits, but they also allow for quick, easy inspections, eliminating the time-consuming process of removing covers or panels for every inspection. They also encourage regular and proactive inspections, enabling the early detection of potential issues before they escalate into costly failures or safety hazards. By avoiding downtime associated with equipment shutdowns and reducing the need for physical access to energized equipment, IR windows can result in significant cost savings.



In addition to thermography testing, NFPA also recommends Ultrasound testing as a means of protecting your electrical assets, especially for rotating equipment. Ultrasound testing is a non-destructive testing technique that uses ultrasonic waves to detect and analyze high-frequency sounds produced by electrical equipment. It can be used for a variety of applications, including the detection of electrical arcing, corona discharge (partial discharge), and insulation defects.

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Partial discharge (PD) in electrical systems refers to localized electrical discharges that occur within insulation materials or along the surfaces of conductors. It is a phenomenon characterized by the release of a small amount of electrical energy in the form of sparks or pulses. These discharges can occur in high-voltage equipment such as transformers, switchgear, cables, and motors and are the result of various factors, including localized insulation defects, contamination, aging, improper installation, mechanical stress, or high-voltage stress. These conditions can lead to the breakdown of the insulating material and the formation of small electrical arcs or sparks.

Detecting and monitoring partial discharge is crucial because it can be an early indication of insulation deterioration or potential equipment failure. Specialized PD detection methods and equipment, such as partial discharge analyzers or ultrasonic devices, are used to identify and quantify partial discharge activity.

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If equipment testing for partial discharge is left unchecked, PD can accelerate the deterioration of insulation materials, reducing their dielectric strength and increasing the risk of complete insulation failure. PD can also generate electromagnetic interference (EMI) and radio frequency interference (RFI), affecting nearby electronic devices and communication systems, and more severely it can lead to the breakdown of insulation and result in electrical faults, equipment failure, or even catastrophic events like electrical arcing or fires.

Monitoring and managing partial discharge activity is essential for ensuring the reliability and safety of electrical systems. Regular inspections, testing, and maintenance practices, such as insulation resistance measurements, partial discharge measurements, and thermography, can help identify and address potential issues before they escalate.

Addressing partial discharge involves identifying and mitigating the underlying causes, repairing or replacing defective insulation, and implementing preventive

maintenance measures to avoid further deterioration.


It is important to note that the specific standards and guidelines for handling partial discharge may vary depending on the type of electrical equipment and the industry. Following applicable industry standards, manufacturer recommendations, and consulting with qualified professionals are essential to effectively address partial discharge concerns in electrical systems.

While Thermography and Ultrasound testing are very important, considered critical, to the maintenance and management of your electrical assets, NFPA also recommends a documented program with well trained, qualified inspectors that are familiar with risk assessment, mitigation plans to potential hazards.

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Documentation: The standard emphasizes the need for proper documentation of maintenance activities. This includes keeping records of inspections, tests, repairs, and replacements to establish an equipment history and aid in future maintenance decisions.






Training and Qualifications: NFPA 70B recognizes the importance of trained personnel for conducting maintenance activities. It provides recommendations for training requirements and qualifications of individuals involved in electrical equipment maintenance.

Risk Assessment: The standard suggests performing risk assessments

to evaluate the potential hazards associated with electrical equipment and prioritize maintenance activities accordingly.

It is important to note that while this summary provides an overview of NFPA 70B, it is always advisable to consult the latest version of the standard for detailed and up-to-date information.



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Like the criticality of an EKG test to one's well-being, so is Thermography and Ultrasound testing to your electrical and mechanical assets providing documented, real-time data...

Protect your ASSETS!



Written by **Alisha Christina McBeth**
Exclusive for transformer-technology.com

Investing in Energy-Efficient Smart Technology Amidst America's Transformer Shortage



Alisha Christina McBeth is an aspiring book author who has been contributing to various international publications for the last decade. Aside from working on her manuscript, she spends her time traveling with her family and three dogs.

The ongoing transformer shortage crisis has led to the disruption of productivity across the country. It has affected energy use in private residential areas and delayed projects in large-scale industries such as construction. This is exhibited by a pause in infrastructure work due to the lack of usable power.

Electrical grids continue to supply power, but this is essentially unusable without transformers to adjust the high voltages into consumable energy. These machines are also tasked with safely distributing electricity to communities and power restoration after calamities. The insufficient amount of transformers, paired with high energy demands, causes intense pressure on the grids. This strain is the primary source of electrical shortages and failures.

This looming threat presents many issues and challenges, but there are ways to mitigate its effects. Specifically, we can turn to new technology for solutions. In this case, smart technology may be the best way to adjust how we use energy and mitigate the transformer shortage.

Electrical grids continue to supply power, but this is essentially unusable without transformers to adjust the high voltages into consumable energy.

What is smart technology?

Smart technology refers to devices typically connected to the internet and made to be controlled digitally. These come in the form of handheld gadgets, household appliances, or heavy machinery. They have been integrated into modern life, with over 60% of American adults owning some variation of smart technology.

Their smart features include advanced systems that allow them to improve machine efficiency and reduce energy waste. Since they are easily accessible, they allow for interconnectivity and flexibility. Users can conveniently monitor and manage their appliances effortlessly no matter where they are. They have been adapted for use in both commercial and residential spaces.



Photo: Pexels, Shutterstock

How can they help with the transformer shortage?

The most important benefit of going with smart technology is the ability to reduce energy consumption. With the help of such appliances, users can improve their power management and lessen unnecessary electrical demand. This is made possible in different ways.

The most important benefit of going with smart technology is the ability to reduce energy consumption.

First, most smart technology comes with **energy-saving features**. Electronic devices with this benefit perform the same task using less energy. This is perfectly demonstrated by home robot vacuums that only use around 60-90 watts of power when operated, compared to traditional upright vacuums, which consume up to 1600 watts. It accomplishes the same task without the high energy costs and amount of maintenance. There are also smart versions of dishwashers that can automatically stop their wash cycles when they detect clean dishes. This feature decreases both water and energy use.

Their accessibility also allows smart devices to be **automated via mobile applications**. This is shown by smart light switches that can be programmed with daily schedules so that they can turn off on their own once there's no need for them. Their illumination strength can also be dimmed on the app so that they require less electricity when they're on. There are also smart ceiling fans that can be switched on and off with one tap on the phone. These kinds of fans have lower energy costs than regular fans, and these can still be reduced by decreasing the fan speed using the app.

This sort of adjustment feature is significant because weather and heat play a vital role in energy consumption. Heating and air conditioning make up half of a household's energy usage. This **temperature regulation** is influenced by seasonal changes and location. Depending on how high the temperature difference is, heating systems end up consuming even more energy to combat it.

To address this, there are smart thermostats that have sensors that can detect temperature and adjust the heating or cooling accordingly without human intervention. Thus, people have the convenience of a comfortable home while enjoying lower energy costs.

Heating and air conditioning make up half of a household's energy usage. To address this, there are smart thermostats that have sensors that can detect temperature and adjust the heating or cooling accordingly without human intervention.

What makes it even better is that all these aspects are available for **monitoring**. Smart devices store data and present them in a way that is understandable by their owners.

**EXPERT OPINION:
ENERGY-EFFICIENT
SMART TECHNOLOGY**



These can usually be found in the partner apps that accompany the appliances. They provide meters that measure rates of use, energy consumption, and other important information that would benefit consumers. Not only is it handy, but researchers have also discovered that such smart meters can influence behavioral changes positively. By observing their consumption patterns and how they affect their expenses, people become more motivated to continue reducing their energy use.

Thus with the help of smart technology, there can be a collective change in how much energy is consumed. Through these, the consequences of the transformer shortage can be alleviated or even avoided.





JFE



thyssenkrupp



bluemint® Steel

Breaking the Ice

Starting to Build a Collaborative Supply Chain for Our Future

During the Apollo 13 space mission a serious failure occurred, forcing the spacecraft's ventilation filtration system to overload. A team of NASA engineers was pulled together to solve the problem. If they failed, a buildup of carbon dioxide would kill the three astronauts on board. The team had a clear mission, and had the pressure of time to inspire their work. The dire consequences of failure gave them the energy and creative capacity to invent a workable solution that the Apollo crew put into place. The astronauts, and the mission, were saved.

The NASA team had less-than-ideal circumstances and resources to solve the problem. They needed to be inventive and creative. They did, however, have ideal conditions for collaboration. Their mission was clear, self-interest was low and there was no competitive tension.

In our mission to save the health of the planet from excess carbon gases, we do not have such ideal conditions for collaboration. In fact, we have serious obstacles to the cooperation and collaboration needed to solve our complex challenges. One team, organization or individual cannot create a solution on their own. We must have the cooperation of many minds to produce results much greater than any individual achievement that could be realized. We have individuals, companies, governments, technical and social teams that all need to contribute to the solution in an inspired and collaborative way. Today, many of these individuals and groups have had crossed purposes, misaligned objectives, strong social disagreements and been driven by self-profit motives. Many have been in strong competition with each other for their organizations or groups to survive. Winning is often seen as a zero-sum (I win – you lose) game. So, we have very challenging conditions for collaboration.

We must, however, find a way to overcome these challenges and redefine what collaboration even looks like.

More than 30 years ago, the Thomas-Killman model for collaboration was developed, and has been used extensively since. The goal is ultimately a win-win for all parties by increasing the level of cooperativeness while driving toward a solution, even if tension arises. At JFE, our first step is confirming that all parties need to work together to redefine what winning is, and open our minds to the fact that we've limited our own beliefs and thinking. In doing so, we understand that multiple parties working together can create unlimited possibilities.



“ Great discoveries and improvements invariably involve the cooperation of many minds.

Alexander Graham Bell



For our future generations, we must agree on a common mission. This is essential to create transformative change and solutions at the pace needed for the health of our planet. Even if our teams have been at competitive or crossed purposes or objectives in the past, together, we must find shared value — including economic value—along with the common mission of decarbonization.

JFE Shoji Power Canada’s initial approach has been to build the common mission within our supply chain, and to define what a winning supply chain looks like. To do so, we must work through our entire supply path, from electrical steel production mills to the transformer equipment component manufacturing and assembly. This means our focus is on:

- Decarbonizing steel making;
- Decarbonizing the processes to make the steel core components; and
- Building the logistics solutions needed to move these materials and components through a collaborative process.

To put this collaboration into place, we require strong partnerships, with a common mission.

During 2021, German-based steel producer thyssenkrupp (TK) was advancing well through the investment and technical challenges of producing reduced-carbon steel products, including carbon-reduced electrical steels for transformers. These materials, branded bluemint®, were brought to the market at the end of 2022 and JFE Shoji was first in line in North America to purchase these materials. The Canadian supply chain team at JFE Shoji has worked for many years to build a strategic relationship with the TK electrical steel (TKES) team.

The deeper conversation regarding bluemint® started with a series of meetings in Japan. Through these deep collaboration sessions between the JFE Shoji and the TKES teams, we found a common mission to supply carbon-reduced steel products to electrical transformer OEMs (Original Equipment Manufacturers), and ultimately North American utilities. As steel production represents around 12% of global carbon emissions, this is a critical step in decarbonizing our whole supply chain. JFE and thyssenkrupp are both environmental leaders and have committed billions of dollars in investments to clean their processes.

At the same time, our team at JFE Shoji started the work to present the idea of lower-carbon steel core parts to its strategic power transformer clients. This requires the leadership of each of the companies to have a similar priority placed on ESG (Environmental, Social and Governance) initiatives. Most companies have ESG policies in place, or are currently developing them. However, the courage to act on those policies, potentially incurring higher expense in a highly competitive market, can feel risky. The leadership team at PTI Transformers, with two production facilities in Canada (Regina and Winnipeg), is highly committed to its ESG principles, and has been recognized as one of Canada’s Best Managed Companies by Deloitte. PTI started business in 1989 as a small maintenance reconditioning shop. It has now grown to be a critical part of the electrical equipment supply chain to many Canadian and US utilities. JFE Shoji has been honoured to be a strategic supply partner with PTI Transformers for more than three decades. Our collaboration on “green,” carbon-reduced electrical steels continues to be a natural fit.



The will of companies, communities and governments to invest in our renewable future, and consequently the electricity grid is there – and we need to make sure that the means of manufacturing the needed equipment, such as transformers, are themselves sustainable.

Georgios Giovanakis, Group CEO
Thyssenkrupp Electrical Steel





Together, PTI Transformers, TKES and JFE Shoji are delighted that the product of our collaboration will produce one of the first certified carbon-reduced power transformers in North America, set for release this summer. The steel production has been completed by TKES, the materials are now in Canada and will start being processed and cut into a 50Mt power core in May of 2023. The large power transformer core will then be shipped to Winnipeg, and the transformer will be built over the following couple of months in PTI's fabricant plant. Finally, the transformer will be proudly put into service by the end of 2023 by SaskPower.

It has taken a great commitment and collaboration from all parties to "break the ice" for this first carbon-reduced transformer. Now, moving beyond one unit to become a larger and more extensive supply chain will require some hard work on all sides. We will need to find the path that will serve the greater needs of a healthier planet. It's one small step that we envision becoming much larger in the upcoming years. It must start with collaboration, a strong collective mission and a will for us all to win.

There are many challenges ahead, but I am confident that we will find a successful path forward, together.



” This is a great example of the partnerships and collaboration required to help with the decarbonization goals in our industry. We, at PTI, are very excited to play a part in this initiative with JFE and TKES and deliver an environmentally responsible transformer to a local customer.

George Jr Partyka, CEO
PTI Transformers

” With PTI, JFE Shoji and thyssenkrupp Electrical Steel, we see very clear examples of companies taking responsibility to reduce their carbon emissions and to support a sustainable energy and steel industry transition.

Georgios Giovanakis, Group CEO
Thyssenkrupp Electrical Steel

Vincent Sprenkle



Photo: Pacific Northwest National Laboratories



“

We are seeing storage impact our daily lives; we're seeing increased variability in the generation from the grid, but then also increased electrification of transportation. There is the desire for other energy storage battery system, so it really spans the gamut of what we are needing and why we are developing more of these storage technologies really trying to push the envelope.

Alan Ross: Hi, I'm Alan Ross.

I'm the Managing Editor of APC Technologies. I have my guest today I am delighted to have: Vincent Sprinkle, the senior technical advisor at Pacific Northwest National Labs. Vince, thank you for joining us.

I love the building, by the way. Behind you there.

Vincent Sprengle: Thank you for having me, Alan.

Yes, we are excited about the new building, the Grid Storage Launchpad, as it's completing construction here.

This has been supported by DOE Office of Electricity, but we will be doing all of our storage work in there. The next generation of electric vehicle batteries or those grains-of-sand batteries, all that will be developed in there.

AR Tell me a little bit about from macro to micro.

What are some of the things that are interesting to you right now?

VS We are seeing storage impact our daily lives; we're seeing increased variability in the generation from the grid, but then also increased electrification of transportation.

There is the desire for other energy storage battery system, so it really spans the gamut of what we are needing and why we are developing more of these storage technologies really trying to push the envelope.

AR Talk to me a little bit about the goal regarding transportation and what's happening in the EV.

What are you trying to do from a storage standpoint there?

VS Our goal is always to be able to get longer range out of the electric vehicles.

That really comes down to how much energy we can pack in kilogram of weight of batteries - watt-hours per kilogram is our primary target that we're looking at. If you look at today's technology, we're in that 250 Watt hours per kilogram.

If we can get the tech to increase the systems up to 500 Watt hours per kilogram, you can double the range for about the same cost, or have the cost of those batteries and make EVs more affordable. We're not doing that predominantly with the materials we have today, so you've got to develop the next generation of materials, prove

that they work and they can hit those standards and that's really what the emphasis of our research is now.

PNNL leads a multi-lab and a university consortium called Battery 500 which is targeting that 500-Watt hours per kilogram goal.

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AR When you think of it, that there's the materials that you use, the manufacturing processes, the design part of it, and PNNL works on every one of those areas.

So you can start at design and work the other way, or you can start manufacturing and say what do you have to do it so you can really plug in.

You just mentioned the 250 to 500 kilowatt hours. That would change the entire EV landscape. Storage driving around and into garages and suddenly it changes what the utilities can do with that when they're actually using the power.

Talk a little bit about the idea of integrating the materials with the manufacturing, with the design, pick anything that you're working on that you think integrates all of those three areas.

VS It is a great point because you do have to look at these systems holistically. You know what is the existing supply chain for materials out there. One of the things that we're working on is sodium ion to replace lithium ion. We can do that because we have less constraints than on lithium supplies. You have access to it, but that supply chain does not currently exist.

How do you take the sodium that we have abundantly in seawater, turn it into the carbonate that we need to go into, make the





battery components? We have the abundance of the mineral, we just don't have the supply chain that we need to develop right now. This is where having the industry come in and help guide the research: here's what we need to see happen before we can get that developed, and that's a large part of the different offices in DOE, and the what the national labs work on, getting that industry input.

In this way we can have impacts at all levels, whether it's the R&D, whether that's supply chain or the manufacturing that's coming up. We need their input, like on manufacturing, to say that something is not going to work for us, or that there is a better way to do it.

One of the things that we're working on is sodium ion to replace lithium ion. We can do that because we have less constraints than on lithium supplies. You have access to it, but that supply chain does not currently exist. How do you take the sodium that we have abundantly in seawater, turn it into the carbonate that we need to go into, make the battery components? We have the abundance of the mineral, we just don't have the supply chain that we need to develop right now.

AR That's excellent. I think that's one of the things that attracted me to PNNL in the first place was the idea that you want you seek out industry impact, but you can impact industry tremendously, we live in a capitalistic market, and if people can capitalize something because it works, it changes industry. I've been concerned about lithium for 10 years because you started to see different regions of the country purchase a lot of the existing lithium available. You kind of said, well, wait a minute, we're going to need more of it, and suddenly we don't control this critical materials marker

That's been a problem, the United States has allowed other organizations, other countries, to take a leadership role in it, and we're going to suffer for it if we don't come up with some positive answers. I know the flow battery that you all helped develop involved vanadium. What was it again?

VS I would say one of the industry standards for flow batteries has been a vanadium flow battery.

There are several commercial entities delivering that type of flow battery. Going back to your question about supply chains and material sources, as we look ahead, how far down the cost curve can we go? Because when we start talking about grid storage, our metric is dollars per kWh. You know, that's what we're focused on.

How do we go and start making this even cheaper than what vanadium could be? That's where we're looking at developing organic molecules that can replace vanadium because at the end of the day, that is still is a commodity material that is subject to changes.

So steelmaking requirements may change and vanadium is the primary hardening agent for stainless steels. That can increase the price and that quickly makes our batteries more expensive.

AR When flow batteries first came out. I was actually on a panel and I remember I got excited about them. This was about 7 years ago and some of the utilities were like, no, this won't apply to us. However, flow batteries are going to change the utility landscape if they're understood, and they really do get applied out there. Talk a little bit about what you think the future of flow batteries is, whether it is the vanadium, redox or any other technology, for the utility industry.

VS You are right, flow batteries in general offer a tremendous amount of potential. If you look at the current landscape today, peak discharge lasts for about four hours. If I want to go from 4 hours to 10 hours, I'm essentially just increasing the size of the tank, and that is a very low-cost option to be able to store more electricity in there. We're seeing that benefit as we want to go towards 12-hour system that can do more shifting of renewables into the night. We look at added resiliency. That's where flow batteries start to come in. It is being able to have those options, because I can just store more electricity at a lower cost.

AR We see data centers now realizing that the generators that they had running on diesel that they didn't change out the diesel. So that when they started them up, they ran for six minutes and stopped. They are replacing all of their diesel with electric generators, so everything just keeps demanding more power.

I'm sure you all are working on something supporting a data center network, because data

centers run the world. I'm a reliability engineer 99.99% and we're seeing a deterioration of that around-the-clock power, so battery storage has got to be an important part of what you're working on for data centers.

VS Data centers or other applications, as you're removing those diesel resources, those batteries need to be able to store more energy. It needs to be able to get you through, if you have a cloud cover with solar. So naturally, as we're trying to remove that and decarbonize a lot of these systems, those battery technologies that are being deployed, do have to work longer.

AR You've heard that if battery technology doesn't change, it's not going to work well. Battery technology is changing, you guys are doing that. That's brilliant work.

I want to go micro for a minute. What is it that that you think is going to be the future of the development of microtechnology for batteries?

VS We've had significant programs. There's a lot of RFID tracking that goes on and those systems do need that power source in the micro battery development program, and again, these are roughly the size of a grain of rice.

Did you know that was developed here in the Northwest, for tracking salmon survivability as they go through the dams? Starting out, these sensors were much larger where you had to do surgery on the salmon to put it in and the survivability rate from that surgery was lower than what you would hope for what they're seeing going over the dams. And so, by being able to miniaturize it, you're actually able to inject it into the juvenile salmon and track them as they are going through the dams. You can get an accurate representation of what the survivability is.

But as you look at other kinds of systems where you would wanted to do it, the more energy we can get into that, the longer we can track, or, if this is going to other technologies, say on deliveries where you would have RFID, you still need that high energy density.

Now we're getting that with what we call primary batteries. They charge once and you cannot recharge, so the goal would be to achieve those same kind of energy densities now, but with the ability to retract or track and reuse those sensors that are developed, and maybe start looking at how to combine that rechargeable small battery on a sensor with some kind of energy harvesting technology. So on larger fish you can do a rechargeable one that picks up the fish

swimming and converts that energy into recharging the battery.

This is the kind of future that gets us excited as to start looking at how we can harvest energy around us, put that into a battery, and be able to use it for the functions that we need to develop.

AR What are some of the things that you think are going to be societal changes? Where do you think our focus needs to be and where, because the Department of Energy supports what you do in a very big way? I think they do a brilliant job of helping, because if you don't have electric power, you're not going to have education, the lights aren't going to work.

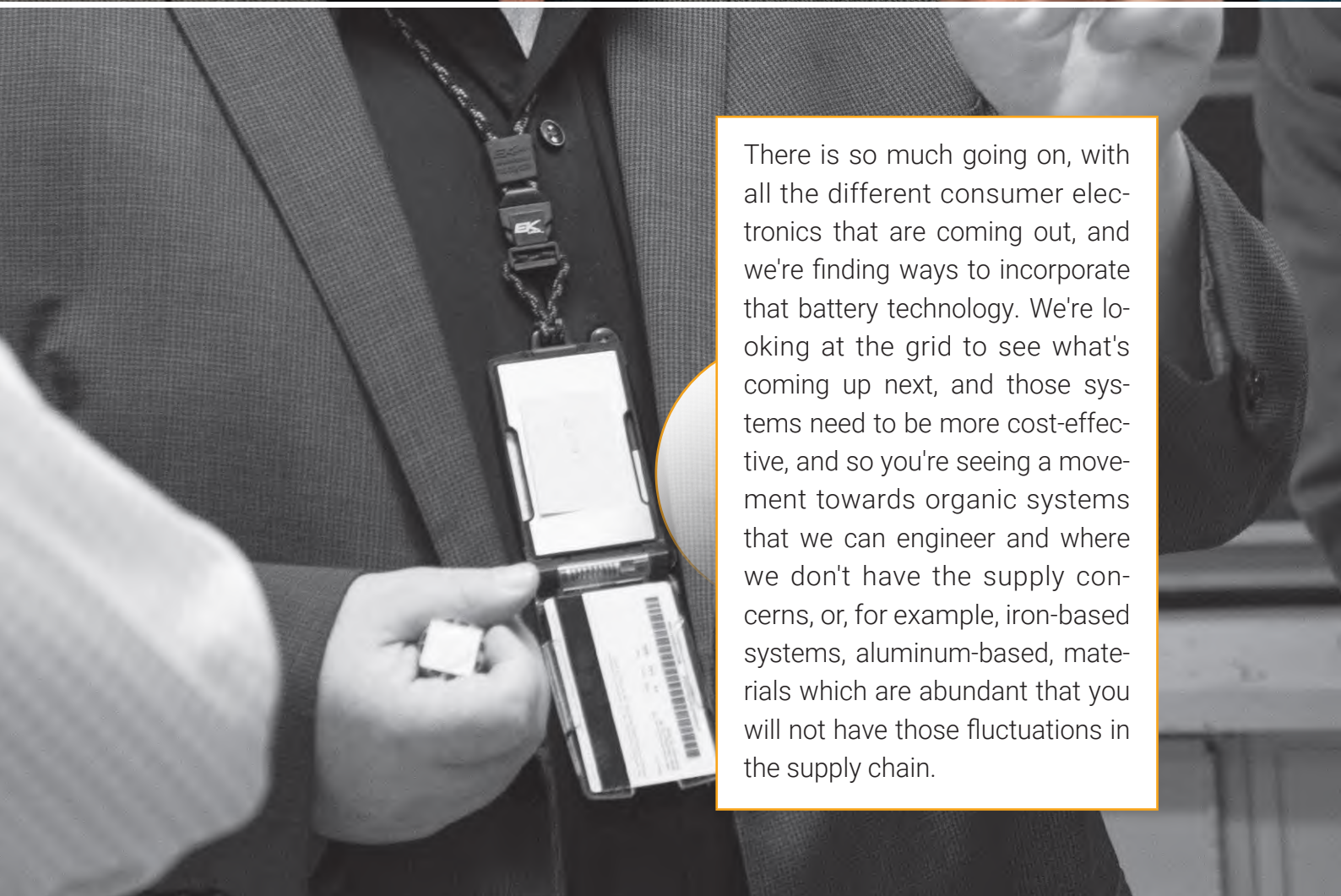
Also, reliability and resilience right now are two big issues. Storage, as you said, plays a huge part of that.

VS There is so much going on, with all the different consumer electronics that are coming out, and we're finding ways to incorporate that battery technology. We're looking at the grid to see what's coming up next, and those systems need to be more cost-effective, and so you're seeing a movement towards organic systems that we can engineer and where we don't have the supply concerns, or, for example, iron-based systems, aluminum-based, materials which are abundant that you will not have those fluctuations in the supply chain.

Utility looks at it and says, I want a 15- to 20-year asset. How do we prove this? That's part of the new building. We'll hopefully get a chance to talk about its goal, which is to validate their expected lifetime. We've already talked about the need for higher energy density, the fast charging is going to be another big effort.

We try to get that down to 5 minutes to charge your EV. That requires significant changes to the chemistries that we're developing. As we start looking at the interaction between the grid and electric vehicles, what can we do when we have a fleet of electric vehicles that comes in at 5 PM to be recharged? Can we manage that to the point where it actually benefits the grid rather than being a huge draw?

We're seeing a lot more emphasis put on the development cycle. First is the end-of-life consideration. I would say seven years ago you weren't carrying that talk. People are considering that now and trying to take that into account. There are tremendous opportunities across the spectrum in terms of different applications, what people are looking for, when it comes to storage. It is exciting time for people coming into the field because there's a lot of options to work on.



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Codes and Standards Governing Battery Safety and Compliance in Building and Fire Regulations

by **Jeff Donato**
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Batteries have greatly influenced the utility industry, but the evolution of battery chemistries has revolutionized their applications. With the emergence of new technologies and advancements in existing ones, standards committees and code writers are working to develop best practices and establish minimum safety guidelines. These groups, comprised of volunteers from diverse industry segments, are actively involved in shaping the standards and model codes that govern battery usage and safety. Their efforts are aimed at keeping pace with the rapidly evolving landscape of battery technology and ensuring its safe and efficient implementation.



Jeff Donato is the Sales Director-Safety Products at H2scan. Jeff Donato has over 25 years of sales and management experience in the industrial battery industry, representing safety and compliance products in the datacenter, utility, and telecommunications applications. Jeff is an active member of the IEEE Power & Energy Society and is the current chair of working group 1578 in the Energy Storage and Stationary Battery Committee (ESSB). Jeff is also a member of several other IEEE working groups including alternative energy storage technologies and the nuclear working group. He has presented standby power system Environmental Health & Safety training to engineering, architect and OEM manufacturing firms and delivered solutions training to end users and specifying engineers.

Battery Applications

Batteries are used in a variety of applications in Battery Energy Storage (BESS). Below is a list of common applications used in the utility market and how batteries are used to support operations:

- **Grid Stabilization:** A stronger grid is required with the increased power requirements and demand being placed on the grid. More devices, including automobiles, are demanding more energy. Energy storage may help stabilize the grid by providing energy back to the grid when the demand rises and store energy when excess power is available.

Energy storage may help stabilize the grid by providing energy back to the grid when the demand rises and store energy when excess power is available.

- **Renewable Energy:** Renewable sources of energy are typically intermittent, and their outputs fluctuate with weather conditions such as with solar and wind. Batteries will store excess energy during periods of high renewable generation and discharge the batteries when generation is low. As a system, this provides a more consistent and reliable source of energy.
- **Microgrids and Off-Grid Systems:** Batteries help create micro grids that can operate independently from the main power grid. In remote areas together with renewable energies, batteries can provide electricity to communities without access to the central power grid.

- **Grid Resilience and Backup Power:** Batteries provide backup power during outages and emergencies. This includes substations that have powered switches, SCADA control systems and end users such as data centers, telecommunications companies, and other mission critical infrastructure for organizations.
- **Demand Response:** Conducted by a utility, batteries can be used where electricity consumers reduce their demand during peak hours in exchange for incentives. This helps reduce peak loads while managing demand fluctuations and alleviate strain on the grid.
- **Peak Shaving:** Consumers can reduce a consumer's maximum hourly power requirement. Knowing the load signature of the building and peak intervals, consumers can use batteries to reduce electric charges from peak usage where price per kW is higher to off-peak usage where the price per kW is lower.
- **Electric Vehicle Integration:** As electric vehicles become more prevalent, EV batteries can be used to store excess renewable energy and discharge it back to the grid during periods of high demand.

Battery Types & Chemistries

Over the years, lead-acid batteries have been the primary choice for utility batteries, enhanced with additives like calcium, antimony, and selenium. These additives were employed to optimize their performance in terms of service life, cycle life, and load profile, specifically tailored for various applications. In environments with demanding conditions, where operating temperatures surpassed the capacity of lead-acid batteries, nickel-cadmium batteries emerged as a crucial solution due to their wider temperature range. However, as the 1990s approached, alternative technologies gained popularity and entered the mainstream.



These included lithium-ion batteries, lithium metal polymer batteries, sodium-based (salt) batteries, flow batteries, and other innovative energy storage technologies.

Each battery type contains different chemistries that has proven beneficial for specific applications:

- **Lithium Ion and Lithium Metal Polymer Batteries:** They include battery chemistries such as Lithium Iron Phosphate (LFP) and Lithium Cobalt Oxide (LCO) which are commonly used in Battery Energy Storage Systems (BESS). They have high energy density, long cycle life and fast response times. Depending on the chemistry, some have higher deflagration potential than others causing fire code to regulate where they can be installed or impose additional site requirements. These batteries are typically used in energy storage applications including grid stabilization, renewable energy, microgrids, demand response, peak shaving, and backup power.
- **Flow Batteries:** They include chemistries such as Vanadium Redox Flow Batteries (VRFB) and Zinc-Bromine Flow Batteries (ZBFB). Flow batteries have advantages with scalability and long duration energy storage (several hours). They store energy in liquid electrolytes contained in separate tanks allowing decoupling of power and energy capacity. Flow batteries are great in applications for load shifting, frequency regulation, and grid backup power.

Flow batteries have advantages with scalability and long duration energy storage (several hours).

- **Sodium-Sulfur (NaS) Batteries:** They have high energy density and long-life cycle making them a good choice for large-scale energy storage. They operate at high temperatures (~300-340°C) and use molten sodium and sulfur as active materials. They provide high output power and are used in grid-level applications to stabilize frequency, smooth renewable energy output, and provide backup power.
- **Lead-Acid Batteries:** Lead Acid batteries: Lead Acid Batteries have been used for decades due to low cost, high reliability, availability of materials and they are recyclable. Vented-Lead Acid (VLA) batteries have free flowing electrolyte, long life, and reliable performance. They are used in most substation and emergency power applications. Absorbed Glass Matt (AGM) and gel batteries are considered non-spillable batteries and have long cycle life with a tolerance to deep cycling. These batteries are used in smaller-scale energy storage, load shifting and emergency backup power.

Safety Standards

Every battery type has specific guidelines for installation, operation, and maintenance, which can be found in the manufacturer's installation

and operations manual. To ensure consistency and best practices across the industry, the IEEE PES Energy Storage and Stationary Battery Committee (ESSB) develops standards documents that cover the characterization, selection, operation, and recommended practices for batteries. In addition, the NFPA (National Fire Protection Association) produces standards documents that focus on electrical safety in relation to batteries. These standards serve as valuable resources for industry professionals and help promote safe and efficient battery usage.

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Figure 1

In addition to the UL standards and other international standards, model building codes play a crucial role in ensuring the safety of battery systems.

Requirement	Description
Electrical Safety	Electric shock, short circuits, and overcurrent conditions
Fire Safety	Thermal management, containment, and suppression systems
Environmental Testing	Temperature extremes, humidity, and vibration
Installation Requirements	Proper installation including electrical connections, ventilation and clearances for safe operation.

Building and Fire Codes mandate that batteries undergo testing according to UL standards or other internationally recognized standards. UL 1973 is a safety standard specifically designed for batteries used in electric vehicles (EVs) and hybrid electric vehicles (HEVs). This comprehensive standard covers a range of critical aspects, including electrical, mechanical, thermal, and environmental considerations. Its primary objective is to minimize the potential risks associated with fire, explosions, and other hazards.

building codes play a crucial role in ensuring the safety of battery systems. Notably, the International Building Code (IBC) includes provisions for the seismic design of battery racks and cabinets. This ensures that these structures can withstand seismic events and maintain the integrity of the battery systems.

Similarly, model fire codes such as Chapter 12 of the International Fire Code (IFC) and the National Fire Protection Association (NFPA) 855 focus on establishing safety requirements specifically for Battery Energy Storage Systems (BESS). These codes serve as comprehensive guidelines that address various aspects of BESS safety.

Figure 2

Minimum to Comply

Battery Technology	IFC Chapter 12 – Min to Comply
Flow Batteries	20 kWh
Lead-Acid Batteries	70 kWh
Lithium-Ion Batteries	20 kWh
Nickel Metal Hydride Batteries	70 kWh
Nickel- Cadmium Batteries	70 kWh
Other Battery Technologies	10 kWh
Other Electrochemical Energy Storage Systems	3 kWh

In the context of Energy Storage Systems (ESS), including Battery Energy Storage Systems (BESS), UL 9540 and 9540A standards have been developed. UL 9540 is the original standard, while 9540A represents the updated version. These standards outline the requirements and guidelines for safe and efficient ESS operation. Fig 1 provides a visual representation of the specific requirements outlined in these standards. Adhering to these UL standards ensures that battery systems meet the necessary safety criteria and helps mitigate potential risks in various applications.

Battery Technology	NFPA 855 – Min to Comply
Lead Acid Batwteries	70 kWh
Ni-Cad/Ni-MH, Ni-Zn	70 kWh
Lithium-Ion Batteries	20 kWh
Sodium Nickel Chloride	20 kWh or 70 kWh if tested to UL 1973
Flow Batteries	20 kWh
Other Battery Technologies	10 kWh
Batteries in one-and-two family dwellings/townhouses	1 kWh

While UL standards are recognized across North America, other regions have similar standards such as IEC 62619 and 62485. Other industry specific standards may cover abusive environments such as Telcordia (Bellcore) Testing Standards.

Model Codes

In addition to the UL standards and other international standards, model

These model codes are widely adopted by states and are sometimes supplemented by local municipalities. Local authorities have the flexibility to make state-adopted codes more stringent, although they cannot relax the requirements, resulting in what is known as a local modified code. A notable example is New York City's FDNY B-28 Fire Code, which incorporates additional provisions from the National Fire Protection Association (NFPA) 855 while complying with the city's adopted International Fire Code (IFC).

To further ensure compliance with the codes, most states and local governments establish minimum system sizes to comply with code and set maximum limits for BESS installations. These size requirements and limitations are crucial for meeting code compliance and are often depicted in guidelines such as Figure 2.

Local authorities have the flexibility to make state-adopted codes more stringent, although they cannot relax the requirements, resulting in what is known as a local modified code. A notable example is New York City's FDNY B-28 Fire Code, which incorporates additional provisions from the National Fire Protection Association (NFPA) 855 while complying with the city's adopted International Fire Code (IFC).

Hazardous Mitigation Plan (HMP)

The model fire codes outline essential safety requirements for both safeguarding Battery Energy Storage Systems (BESS) and ensuring the protection of individuals. It is strongly advised to include the items listed in the Battery Safety Requirements table (Fig 3) in your Hazardous Mitigation Plan (HMP) for the battery system. These items encompass the following:

- **Identify the hazards:** Fire, explosion, chemical risks, electrical hazards, environmental impacts.
- **Assess the risk to your site:** Identify the consequences to the above risks.
- **Safety Measures:** Implement safety measures to prevent or mitigate hazards.
 - Designing engineering controls to prevent and mitigate hazards.
 - Creating the operating procedures
 - Develop a training program.
 - Assess the fire system for the battery technology.
 - Assess the ventilation, gas detection and environmental controls.
 - Document the Emergency Response Plan (ERP)
 - Document all maintenance activity and inspections.
- **Document and communication:** Maintain detailed safety inspection records, training sessions, hazards, safety procedures, and emergency response protocols.
- **Perform an ongoing improvement plan:** Update the site based on codes & standards updates and safety inspection findings.

By adhering to these guidelines and incorporating them into your Hazardous Mitigation Plan, you can enhance the safety and security of your battery system and effectively manage potential risks.



Figure 3

Battery Safety Requirements

Item	Code/Regulation/Standard	Description
Explosion Control	IFC section 1207.6.3 NFPA 855 section 9.6.5.6	Batteries with high deflagration rates are required to install prevention systems and venting.
Safety Caps	IFC section 1207.6.4 NFPA 855 section 9.6.5.4	Required to prevent flame from entering a battery.
Exhaust / Ventilation	IFC section 1207.6.1 NFPA 855 section 4.9, 9.6.5.1 IEEE 1635/ASHRE 21	Required for all batteries that could gas. Explosive gasses need to be kept within 25% of the Lower Explosion Limit. This may include a Hazard Mitigation Analysis (HMA) to determine gassing levels per IEEE 1635/ASHRE 21. Hydrogen detection may be a part of the HMA to connect to an exhaust fan and annunciate and alarm condition.
Spill Control & Neutralization	IFC section 1207.6.2 NFPA 855 sections 9.6.5.2, 9.6.5.3 IEEE 1578	Prevents free-flowing electrolyte from creating an unsafe condition.
Thermal Runaway	IFC section 1207.6.5 NFPA 855 section 9.6.5.5	Required for lead-acid, Ni-Cad, Ni-MH, Lithium-ion, and other technology types that could go into thermal runaway
PPE	OSHA 1926.441(a)(5) NFPA 70E article 320	Eye Protection, Face Shields, Acid Resistant Apron, Acid Resistant Gloves
Eyewash	OSHA 1926.441(a)(6) ANSI 358.1	Primary eyewash devices must be installed with all aqueous batteries
Shrouds & Shields	OSHA 29 CFR 1910.308 (a)(7)(IV) OSHA 29 CFR 1910.333(a) OSHA 29 CFR 1910.333(c)(5) OSHA 29 CFR 1910.335 NFPA 70E	Shrouds and shields shall be installed on all connections with dangerous voltage to protect people from incidental contact
Signage	OSHA 29CFR 1910 IFC section 1207.4.8 NFPA-1 section 52.1.18.1 NFPA 855 section G.1.4.2 NFPA 70e section 310.5 (B) ANSI Z535 ANSI 358.1	Warning signs are required to notify of dangerous voltage, hazard identification (type of technology), emergency contact, emergency shutdown, fire suppression system installed

It should be noted that not all battery chemistries are suitable for every application. Therefore, engineers must carefully consider the distinct characteristics, maintenance requirements, and operational prerequisites of each technology before implementation.

Conclusion

Battery technology has undergone significant advancements since the 1990s, introducing a range of new and exciting chemistries to cater to the increasing demands of the power grid. As these technologies start to materialize in practical applications, ensuring safety becomes crucial for their successful operation. This involves the establishment of safety testing standards and the implementation of site and personal

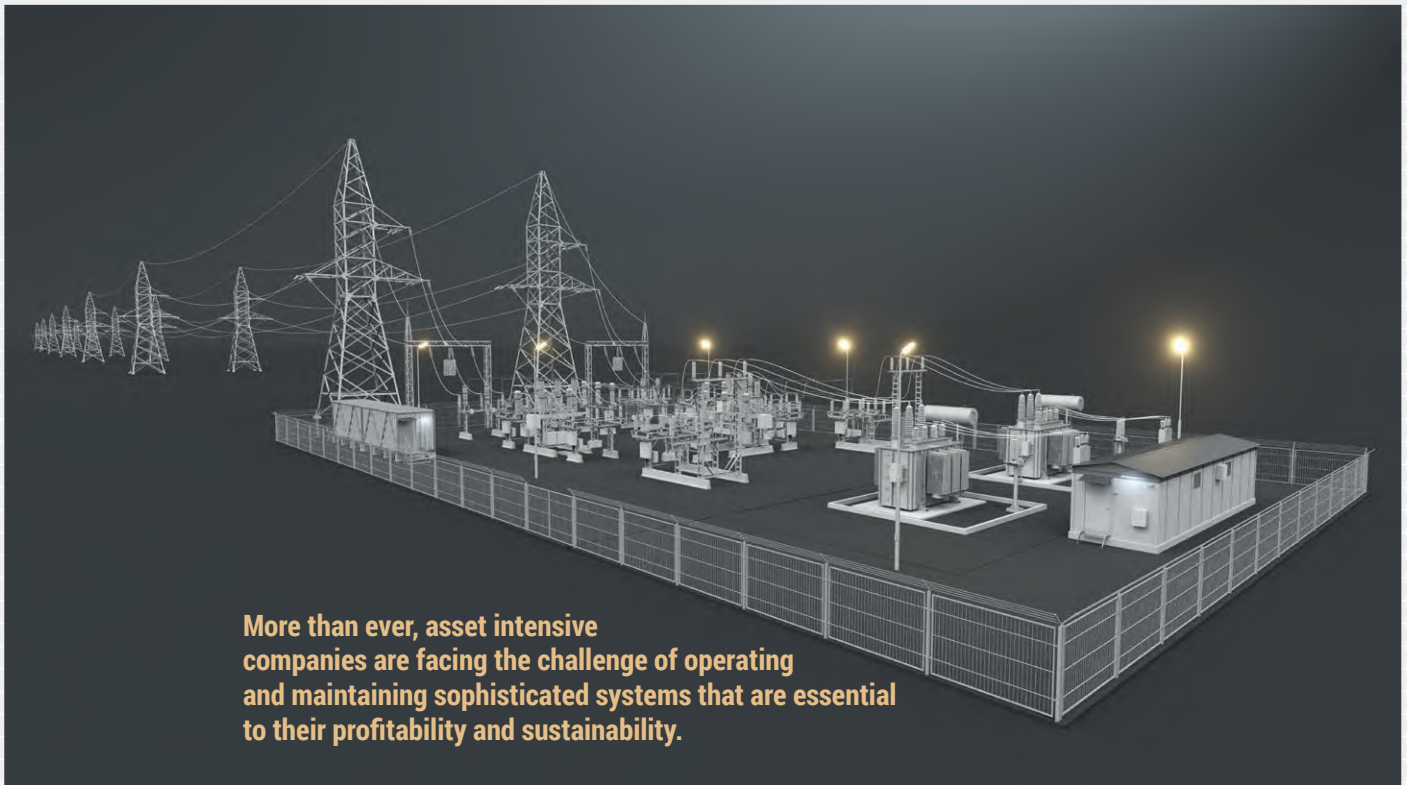
safety protocols. It should be noted that not all battery chemistries are suitable for every application. Therefore, engineers must carefully consider the distinct characteristics, maintenance requirements, and operational prerequisites of each technology before implementation. Additionally, regulatory bodies responsible for enforcing safety measures will adapt model codes to incorporate specific attributes relevant to their respective states or municipalities.

Digital Twins

Applied to
Power Grids



HEXACODE
SOLUTIONS



More than ever, asset intensive companies are facing the challenge of operating and maintaining sophisticated systems that are essential to their profitability and sustainability.

All new infrastructure projects today are delivered using Building Information Modeling (BIM). The challenge for most organizations is to find ways to take advantage of data and information generated during design and construction to optimize operations during the lifecycle of the assets involved. This implies defining, before design activities are taking place, which information needs to be supplied in the 3D models to support both commissioning and operations activities.

More than ever, asset intensive companies are facing the challenge of operating and maintaining sophisticated systems that are essential to their profitability and sustainability. Electrical utilities are dealing with supply chain problems due to high energy demands and assets nearing or exceeding design life. The integration of distributed energy resources adds a new level of complexity. Utilities also have to manage an aging workforce which brings a knowledge gap difficult to solve.

In order to respond to these challenges, today's asset management systems are evolving towards condition-based, predictive, and prescriptive solutions. We are also witnessing the emergence of Artificial Intelligence solutions that will ultimately enable us to better anticipate failures. The evaluation of the condition of assets and components require the deployment of Asset Performance Management (APM) solutions capable of dissecting assets down to their most significant components. This detailed (component level) inventory is not only essential for condition assessment and predictive analytics, but also for the application of Artificial Intelligence/Machine Learning algorithms. The level of detail in the 3D model used during the design and construction phases has to be determined with these requirements in mind.

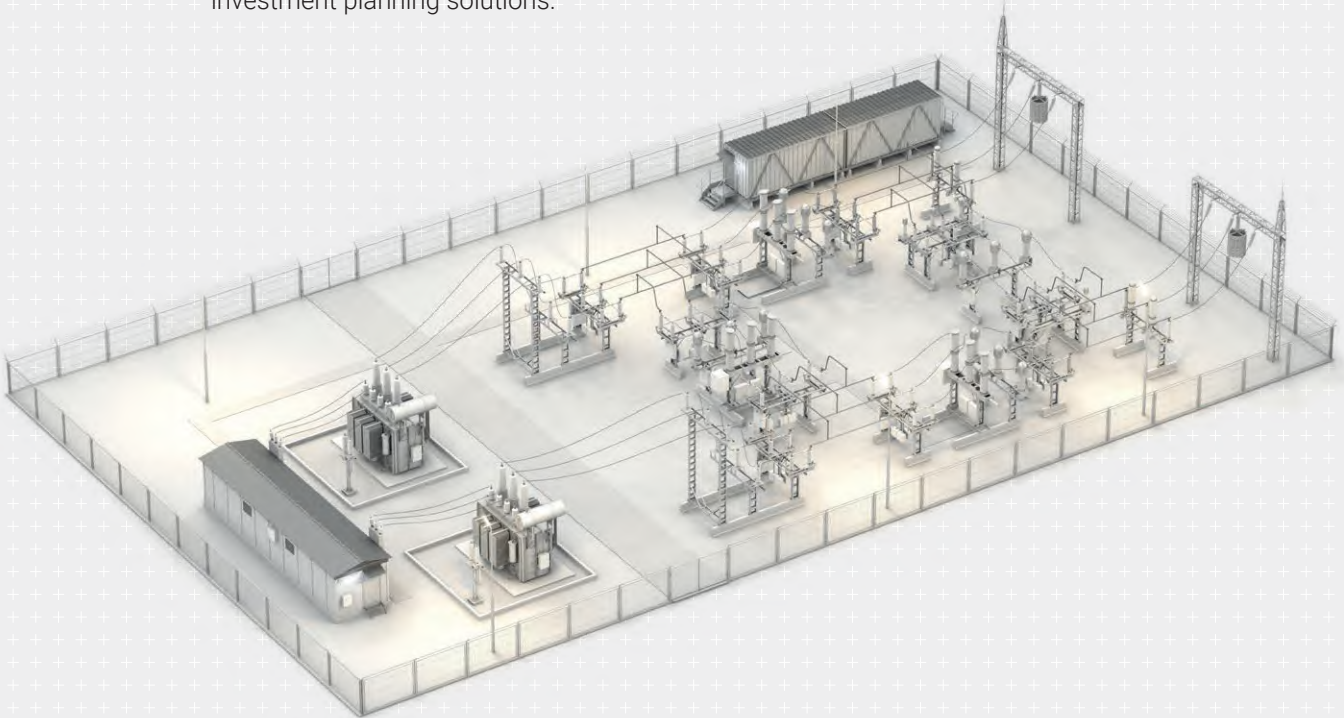
Solutions provided by many technology suppliers meet the accepted definition of a digital twin, e.g., a digital representation of an intended or actual real-world physical product. The word intended refers to the design and construction/manufacturing. The word actual refers to assets in operations. Digital twins in the design phase include activities such as digital simulation, computer-aided design, clash detection, work sequences, and stress analysis.

Digital Twins in the operations phase have various value propositions. For instance, one proposition could be to deliver dynamic rating of a power transformer taking into account the thermal model of the transformer, load forecast, and expected environmental changes such as temperature and wind.

There are three types of digital twins:

- Digital Twin Prototype (DTP): designs, analyses, and processes to realize a physical asset.
- Digital Twin Instance (DTI): digital representation of an individual process or asset.
- Digital Twin Aggregate (DTA): asset or system data and information for prognostics, performance analyses, and learning.

We will focus on applying a DTA in the form of a next generation Asset Performance Management (APM) solution that extends assets and components life by applying degradation algorithms at the component level. We will cover some important elements in creating digital twins such as level of details, integration with existing IT/OT systems, scalability, component level analysis and integration with asset investment planning solutions.



3D model and Level of Details

As we saw earlier, the DTA collects data and information generated during the design and construction phases. The use case we are presenting here requires a level of detail that allows the identification of the main components and sub-components. As this level of detail is not required for the design stage, the 3D models used for design and construction do not normally include this information. It is also important to consider that a higher level of detail also leads to a significant increase in the 3D model file size, making it difficult to manipulate during design, construction and operations. The detailed information is normally supplied by manufacturers documentation (instruction manuals, drawings, 3D models) and integrated directly in the models hosted in the APM. These detailed models also apply to assets that were commissioned before 3D models were in use.

In order to apply both simple and complex degradation algorithms to a large number of assets and components, the introduction of asset and component models in the APM is essential. These models can be generic or specific to a manufacturer. They contain the basic characteristics used to specify the asset or component, and to select the proper condition assessment and predictive analysis calculations. Each asset and component in the APM inventory are linked to a model. Information such as asset location, loading, environment, usage, performance is then captured in the APM by integrating with existing IT/OT systems. The APM detailed inventory allows to dissect assets down to the component level and to follow changes during the entire lifecycle.



Building Information Modeling (BIM) has different levels:

- BIM 3D = Geometry
- BIM 4D = Time
- BIM 5D = Cost
- BIM 6D = Sustainability
- BIM 7D = Operations

The APM use case that we are presenting is BIM 7D+ (the plus sign means real-time). This APM supports the integration of artificial intelligence algorithms at the component level. It can host the AI/ML algorithms or integrate the results. In fact, the APM can have the AI/ML coexist with its knowledge-based algorithms. Another important element to consider is that components of an asset can be replaced over time which has a positive impact on the overall condition of the asset. A digital twin has to be able to track these changes during the entire lifecycle. This is enabled by introducing the concept of component commissioning and the use of an event driven database.

APM Integration with Existing IT/OT systems

Accessing, validating and updating various data sources is a costly process, replete with inefficiencies. Information generally originates from different business units, IT and OT systems. The source of information can either be 3D models, GIS, Excel spreadsheets, EAM/CMMS, SCADA, ERP, Historian, databases or probes. The integration can be done through scripts, API, protocols or data extractions. The APM extracts or host information and data that are essential to perform condition assessment, and predictive analysis calculations and support decision making. The APM also incorporates data validation capabilities and share results in a bidirectional way with IT/OT systems.

In critical infrastructures the need for real-time calculation capabilities for an APM is mostly associated with degradation mechanism such as vibrations. To capture these events time stamps of 1 ms are necessary. For most of the other parameters, the APM has to be able to integrate them either through probes, test instruments or visual inspections in order to perform interpretations and calculations. The APM also needs to be able to send alarms if one parameter is out of a prescribed range (including those collected through visual inspections).

Scalability

When dealing with electrical utilities, the number of assets is staggering. Utilities must deal with station equipment (power transformers, circuit breakers, inductances, and switches) and cover millions of transmission and distribution assets (power lines, poles, distribution transformers, underground cables, and lines) of various costs and criticality. Most of the APM in the market today are derived from existing EAM designed for industrial applications where the number of assets and components rarely exceed 10,000. When managing millions of assets, these APM technologies may encounter performance issues (user interface responsiveness, calculation speed, time stamps, level of detail).

Importance of Condition Assessment at the asset and component levels

If properly implemented, condition-based asset management brings vital information for OPEX and CAPEX optimization that asset monitoring cannot deliver alone. If a system monitors each important parameter of an asset or component but doesn't provide condition score 0-100% based on the state of degradation of these components, setting priorities on maintenance activities or capital planning decisions becomes extremely time consuming or impossible because of the number of assets involved. If you add the complexity of determining the impact of failures in order to evaluate risks, decisions makers have to rely on accurate condition assessment information, not just degradation curves.

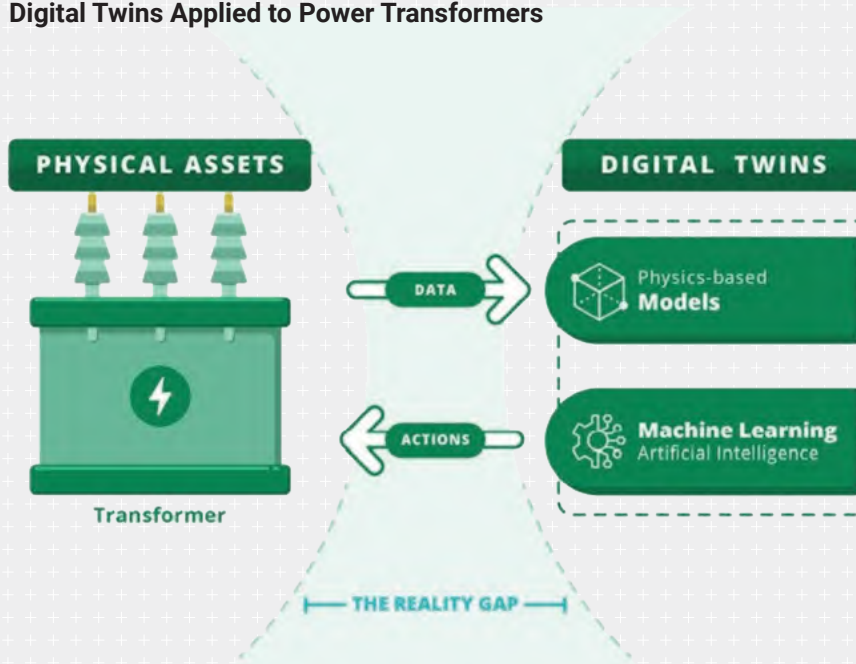
If properly implemented, condition-based asset management brings vital information for OPEX and CAPEX optimization that asset monitoring cannot deliver alone.

The APM must also be able to go back in history to access inventory changes down to each descriptive field and also for inspections and tests results and statistics at the model level. This functionality enables management to gather information on which changes have been made to assets and how the condition of specific asset model has evolved between two specific dates.

Integration with Asset Investment Planning solutions

Asset Investment Planning (AIP) software solutions are providing mid to long term investment scenarios based on statistics and available asset data. These systems use degradation curves that rely on statistics as well as criticality, financial information and business objectives. In order to improve the accuracy of the overall investment planning process, several infrastructure owners now require that the investment scenarios be based on condition assessments derived directly from inspections and tests. This is where component and asset level condition results combined with predictive and prescriptive analysis can make a huge difference by providing the latest and most accurate asset information to the existing AIP. A scalable APM that assesses assets and their components, takes available asset information for OPEX and CAPEX optimization to another level.

Digital Twins Applied to Power Transformers



Source: CIGRE JWG Proposal: Transformer Digital Twin – concept and future perspectives, February 16th 2022.

A new CIGRE working group was created to evaluate the functional behaviors of power transformers in real-time, to understand the 'reality gap' and to integrate digital twins in utilities operations and maintenance systems. This working group, which takes into consideration the knowledge-based and machine learning approaches, will lead to a better understanding of complex assets. This confirms the soundness of our design allowing the two approaches to coexist at the component level.

In light of the recent developments in the digital twin field, and in phase with CIGRE's initiatives, HEXACODE proposes an innovative APM solution that solves both scalability and complexity issues associated with electrical utilities assets.



Hexacode's Digital Twin allows the use of complex degradation algorithms to generate at the asset and component levels, the Condition Assessment (CA), the Asset Health Index (AHI), and predictive analysis.

HEXACODE Solution

In light of the recent developments in the digital twin field, and in phase with CIGRE's initiatives, HEXACODE proposes an innovative APM solution that solves both scalability and complexity issues associated with electrical utilities assets.

HEXACODE's APM main characteristics:

- Allows information gathering from various IT/OT sources.
- Generates an operational inventory and provide links to photos, documents, drawings, 3D, GIS, and URLs relative to specific assets or components.
- Generates predictive analysis (alerts, warnings, notifications).
- Multilingual.

Key Differentiators:

- Tracks inventory and asset description changes at any given date.
- Manages inspections and tests data specific to asset and component models.
- Isolates any sub-component and calculates in real-time the Condition Assessment, the Asset Health Index and Alarms (based on its specific degradation mode).
- Time stamp of 1 ms.
- Allows the coexistence of multiple calculations based on different methodologies.
- Creates relations between assets (i.e., identify isolating points/sources in systems).
- Capability to generate diagnostics and prescriptive analysis at the component level.
- Provides real-time dashboards for asset status visualization integrating Geohash with Google Maps, and Leaflet maps.
- Offer an ultra-responsive user interface (< 500 ms).
- Generates real-time and historical statistics for assets models and categories.
- Manages offline inventory modifications, inspections and tests.
- Manages millions of assets and components on-premise or in the Cloud (25 million objects per server).

Conclusion

Altogether, the HEXACODE solution delivers accurate data at the component and asset levels in order to generate meaningful insights for OPEX and CAPEX optimization. This information is critical for today's asset intensive businesses. HEXACODE's APM is differentiated by an advanced Condition Assessment and Asset Health Index methodology applied at the level of components.

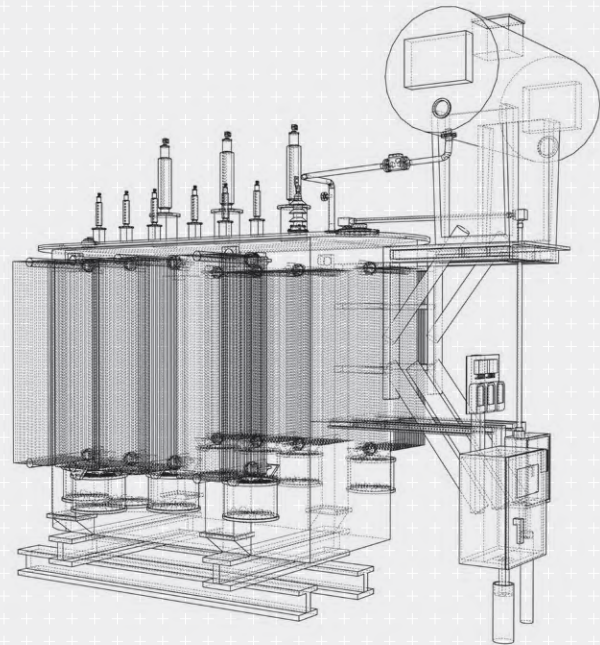
Hexacode's Digital Twin allows the use of complex degradation algorithms to generate at the asset and component levels, the Condition Assessment (CA), the Asset Health Index (AHI), and predictive analysis. It can use/create/adapt degradation models from various sources (normative, state of the art, scientific, and customer expertise), consequently allowing collaboration and partnerships. Also, several algorithms' calculations can coexist for the same component in real time, allowing the selection of the most accurate degradation interpretations.

Hexacode's APM can be applied to any electrical, mechanical or civil assets, including assets that were not modeled using 3D. The deployment of the functionalities can encompass all assets or only the critical ones. It can also be applied to industrial processes and other critical infrastructures including rail transportation, data centers, telecommunications, airports. The existing IT/OT architecture remains the same and the APM extracts or hosts the asset information under a single easy to use mobile interface.

Condition assessment, predictive and prescriptive analysis support sustainability objectives by extending assets life while managing risk and are positively impacting today's most pressing asset management challenges.



Jean-Pierre Girard, has over 35 years of experience in the electronic and electrical equipment field, with management responsibilities in application engineering, service, product safety, process improvement, quality management, and electronic business. He has acquired expertise in asset management applied to critical infrastructures and has been a speaker on this subject internationally. He worked at Siemens for 22 years and held several management positions. From 2001 to 2008, Mr. Girard was Executive Director responsible for Hydro-Québec and SNC-Lavalin, representing all Siemens business units. Mr. Girard was a member of the Board of Directors of the Quebec Electrical Industry Association. He has been involved internationally on numerous business committees and company-wide transformation initiatives. He is the founder of HEXACODE Solutions. (jgirard@hexacode.ca)



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Distribution-Center-in-a-Box as an application of Voltage Regulating Distribution Transformers

by **Tu-Anh Tran**
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Patrick Wright
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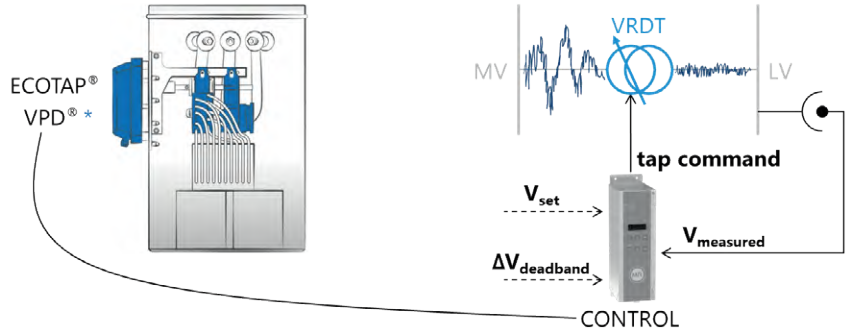




Tu-Anh Tran works as Business Development Manager for Maschinenfabrik Reinhausen, a subsidiary of the Reinhausen Group. She engages with utilities, industry partners and relevant stakeholders to adopt voltage regulation technology for the distribution grids. As a solution that solves several distribution grid challenges due to emerging trends, Tu Anh works with utilities and industry partners to adopt this smart-grid technology as part of grid modernization and grid reinforcement efforts.

Distribution transformer with LTC

Autonomous regulation by control unit



* Single- (displayed) or three-phase version available

Figure 1. Voltage Regulating Distribution Transformer

1. Introduction

Population growth and electrification trends are major drivers for increasing loads on the US electric distribution systems. Utilities continue to develop new strategies and devise innovative ways to design, engineer and construct substations and transformer equipment. Combined with the increasing needs to lower capital expenditure due to regulatory and ratepayer pressure, utilities often look for ways to innovate. As part of this initiative, the distribution center in a box (DCIAB) project was developed as a new application for voltage regulating distribution transformers.

1.1 Voltage Regulating Distribution Transformers (VRDT)

Traditionally, voltage regulation can be done by using an off circuit tap changer, which allows for transformer windings to be added or subtracted in distinct steps only when the tap changer is de-energized.

Voltage regulating distribution transformers (VRDT) belong to a new class of distribution transformers that are equipped with an on-load tap-changer to enable a stable voltage output under load.

Standard grid planning follows ANSI C84, requiring distribution system voltages to be within ±5% of nominal voltage with respect to 10-minute average voltage [1]. Voltage regulation from primary feeders is distributed throughout the entire distribution lines, creating a voltage limit constraint within the voltage bandwidth. At the primary substation feeders, voltage usually remains stable and independent of the feed in load. However, the delivered voltage experiences a larger spread further down the distribution line. In conventional distribution transformers, voltage on the primary side is linked to voltage on the secondary side. The effect of this mechanism means high voltage on the primary side equates to high voltage on the secondary side. With the implementation of a voltage regulating distribution transformer, a decoupling effect takes place between the medium and low voltage grid [2]. From the distribution voltage profile, voltage starting from the substation to the line voltage regulator may be above nominal voltage so that there is room for voltage drop over the distribution transformer to the connection points of the last meter in the line. This is true for both peak load and low load scenario.



First Gen DCIAB

- 9.375 MVA
- 34.4 kV HV - 200 kV BIL
- 13.2 kV LV – 110 kV BIL rating
- 34.5 kV lightning arresters, 200 kV BIL
- 65°C rise ONAN
- De-energized tap changer with $\pm 2 \times 2.616\%$ tap
- Three 333-A single phase regulators
- Dimensions: 121.3 (L) 140.6 (W) 117.9 (H) inches
- Oil volume = 1320 gallons

Next Gen DCIAB

- 9.375 MVA
- 34.4 kV Delta HV - 200 kV BIL Primary
- 13.2 Y/7.6 kV LV - 110 kV BIL rating
- Nominal Impedance: 6.5%
- 65°C rise ONAN
- ECOTAP® VPD® 3-phase 40.5 kV 100-A LTC
 - ~12 operations/day
- Dimensions: 121.3 (L) 140.6 (W) 117.9 (H) inches
- Oil volume = 1314 gallons
- Total weight = 43,500 pounds

Table 1. First Gen vs. Next Gen DCIAB Comparison

The VRDT decouples MV from LV grid such that any voltage that comes from the primary side, it does not affect the voltage on the secondary side. Connected customer meters continue to receive stable secondary voltage despite the condition of the voltage from the primary side.

From the distribution voltage profile, voltage starting from the substation to the line voltage regulator may be above nominal voltage so that there is room for voltage drop over the distribution transformer to the connection points of the last meter in the line. This is true for both peak load and low load scenario.

1.2 OLTC Specifications

A standard distribution transformer integrated with an on-load tap-changer becomes a voltage regulating distribution transformer (VRDT). Manufactured by Maschinenfabrik Reinhausen, the ECOTAP® VPD® is a compact load tap changer that enables service transformers to respond to changes in voltage under load. Having the ability to respond to changes in voltage under load and the decoupling

of medium voltage from low voltage grids, the VRDT opens up various potential applications for utilities, industries and distributed generation.

Based on a high speed, resistor-type vacuum technology, this OLTC can operate either in 9 or 17 positions at 1.25 or 2.5 percent per step in common configurations. Designed for single phase and three phase, the equipment is rated at 30 A or 100 A, with the highest equipment voltage at 40.5 kV. The ECOTAP® VPD® OLTC exemplifies high reliability by enabling 500,000 operations exceeding the typical lifetime of the transformer. The ECOTAP® VPD® comes with motor drive, the load tap changer and a control unit.

2. DCIAB as an application of VRDTs

2.1 ComEd Overview

Commonwealth Edison Company, also known as ComEd, is the largest electric utility in the state of Illinois, serving 4 million customers throughout northern Illinois and 70% of the state’s population. ComEd provides electric services within an 11,400-square-mile territory and manages over 90,000 miles of power lines [3]. In 2012, as part of the Illinois Energy Infrastructure Modernization Act, ComEd stepped up significant electric grid improvements throughout its service area through a 10-year grid modernization plan [4].



Figure 2. A traditional substation that requires easement, fencing and wildlife protection



Figure 3.
First Gen DCIAB [5]



Figure 4.
Next Gen DCIAB



The utility recognizes the needs for a strong and modern electric grid as the basis for its modernization plan. As a result, grid infrastructure upgrades are part of the core initiatives at ComEd.

2.2 First Gen Distribution Center-in-a-Box

The first generation DCIAB project started in 2005 as part of the initiative within ComEd’s Innovation Team. Driven by efforts to be more cost effective, the team came together with equipment manufacturers to design the existing equipment, a substation design project called Substation-in-a-Box. This equipment is a line voltage regulator in the form of a 34.4 kV substation with 3 single-phase voltage regulators and a switch.

Driven by efforts to be more cost effective, the team came together with equipment manufacturers to design the existing equipment, a substation design project called Substation-in-a-Box.

The transformer is equipped with a 600-A recloser that is connected inside the LV air compartment. The recloser controls are mounted on the outside of the cable compartment for accessibility.

This design made a big leap, transforming a typical distribution center substation into a more compact solution and therefore enabled ComEd to add distribution services directly at the location where the growing loads requirements exist.

The 2005 DCIAB project serves to increase reliability and reduce substation design and construction costs. Unlike the traditional distribution center substation layout, which requires security fencing for overhead incoming and outgoing wires, to and from the exposed transformer bushings, the pad-mounted DCIAB style allows both the 34.5 kV and the 13.2 kV lines to run underground. This new concept, with its reduced footprint, would be unfenced, with less overhead lines that leads to better visual aesthetic to the community.

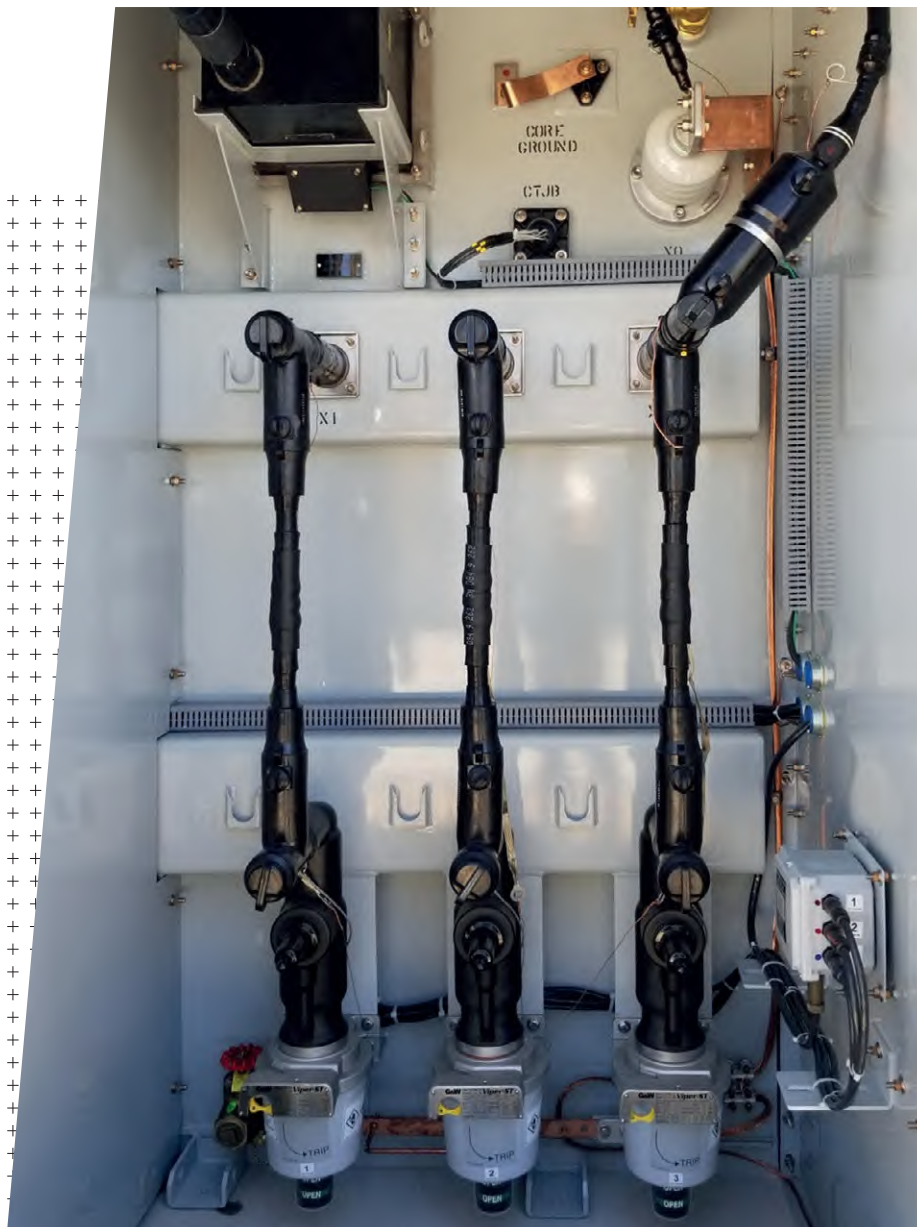


Figure 5.
Cable connections are dead-front inside the pad-mounted transformer

2.3 Next Gen Distribution-Center-in-a-Box (DCIAB)

Located 100 miles southwest of Chicago, the rural town of Tonica is a village in LaSalle County, Illinois. Economic growth in Tonica fueled the need for additional substation capacity. In 2019, a ComEd team went to the drawing board and came up with a re-design of the existing First Gen DCIAB.

The next generation DCIAB features a novel design with several new characteristics. The 3 individual single phase voltage regulators are now replaced with an on-load tap-changer (LTC), the ECOTAP® VPD® from Maschinenfabrik Reinhausen, further

reducing the footprint of the substation significantly. It is installed on the high side voltage with a regulating range of $\pm 10\%$. The 40.5 kV, 100-A three-phase LTC provides the same capability as the previous 3 individual single-phase voltage regulators, enabling voltage regulation under load to ensure Tonica residents receive voltage within the prescribed limit.

As part of the project's priorities based on safety and reliability, the DCIAB retained its dead front design to enhance safety for operating personnel, a cornerstone feature in the previous version of the equipment. In addition, a de-energized tap changer is also added for safety and convenience while maintaining equipment.

2.4 Cost Benefit Analysis of Next Gen DCIAB

Compared to the first gen DCIAB, the next gen DCIAB features a significantly smaller footprint than its predecessor. This allows for a single 34kV to 13.2 kV transformer to be installed "right-of-way" without building a substation or the needs for additional fencing and wildlife protection. The total cost estimate for the current DCIAB transformer equipment is approximately half of its original model, as illustrated in the table below.

Compared to the first gen DCIAB, the next gen DCIAB features a significantly smaller footprint than its predecessor. This allows for a single 34kV to 13.2 kV transformer to be installed "right-of-way" without building a substation or the needs for additional fencing and wildlife protection.

ComEd commissioned the DCIAB project in October of 2020 and subsequently energized the project in March 2021.

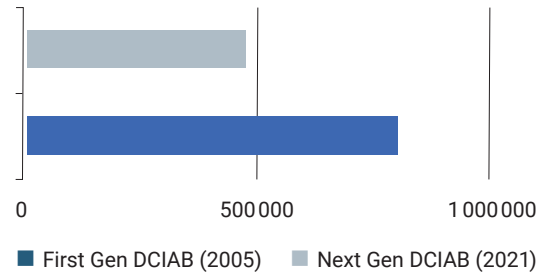
3. Conclusion

A new class of distribution transformers, the voltage regulating distribution transformer, is fast becoming an important and economical solution for grid operators to solve challenges for the distribution grids. These challenges stem from the increased loads due to electrification movement, distributed energy resources, and regulatory pressure to reduce capital expenditures as a benefit to ratepayers. The DCIAB project from Commonwealth Edison is a clear example of its viability in the grid operators' toolkit. For ComEd, it is now the new standard for DCIAB designs. For other US utilities, new applications continue to be assessed where the VRDT may serve as a beneficial solution for the distribution grids.

First Gen DCIAB (2005) Next Gen DCIAB (2021)

DCIAB Cost Comparison

Transformer	92,50%	100,00%
Land Easement	6,25%	0,00%
Fencing	1,25%	0,00%
Total Project Cost (in %)	100,00%	100,00%



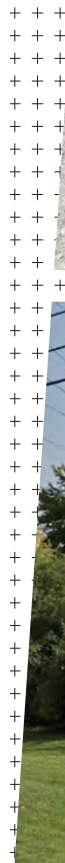
*Table 2.
DCIAB Cost Comparison*

Project estimates do not include additional easement for fencing, equipment foundations, civil work, mid-grade or high-grade fencing.

A new class of distribution transformers, the voltage regulating distribution transformer, is fast becoming an important and economical solution for grid operators to solve challenges for the distribution grids.

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Siti Munirah

My name is **Siti Munirah** and I joined Hitachi Energy's predecessor in 2011. I started my career as a graduate trainee in the High Voltage Products Business Unit and as such I underwent a year of training before being given the responsibility of Project Engineer. I am primarily responsible for sales support, project management and supporting the service team during their sales activities. Besides assisting the service team, part of my responsibilities also includes managing projects assigned to me.

In 2011, we were in the early stages of business operations in Malaysia, and the High Voltage Products team was a relatively lean team. As the first female engineer, I was pleasantly surprised upon joining the team, as I had the wrong notion that office-based tasks were done and managed only by female employees.

Here in Hitachi Energy, all tasks are shared equally among the team members, regardless of gender - from project management and scheduling to sales documentation, from purchasing and logistics to internal audits, and arranging materials and high-voltage equipment for customer sites; every team member is involved. My colleagues are very supportive, and they made sure to help me along the way.

I also got many opportunities to tag along with them, meeting customers and observing their site work.

With all the collaboration and caring spirit, the team was more like a family. Communication within the team was always open and being from different positions within the company, never stopped anyone from getting involved and sharing their opinions and suggestions. It gave me the confidence to take up new tasks and I started seeing complex tasks as a bonus. I saw it as an opportunity to challenge myself and polish my soft skills further.

This environment gave me a lot of positive vibes and because of this, I started achieving good business results in just two years. I am extremely proud of this since I felt that my efforts and struggles had finally paid off.

Being in the High Voltage Products Business Unit, I was exposed to many sales and after-sales solutions in the power industry. Everything must be on point, fast, informative, and competitive in the power industry. Good customer engagement is essential, so that they can be updated timely on the

latest products and solutions to receive our full support.

To women out there, don't be afraid to try and take on challenges if you want to start your career in the power industry. It does have a place for us to fit in and change the stereotypical working perception in this industry.

I can truthfully say that having us women in the workplace will add a lot of value by contributing our thoughts and support, including adding a bit of cheerfulness along the way.



Don't be afraid to try and take on challenges if you want to start your career in the power industry.

Communication within the team was always open and being from different positions within the company, never stopped anyone from getting involved and sharing their opinions and suggestions. It gave me the confidence to take up new tasks and I started seeing complex tasks as a bonus.

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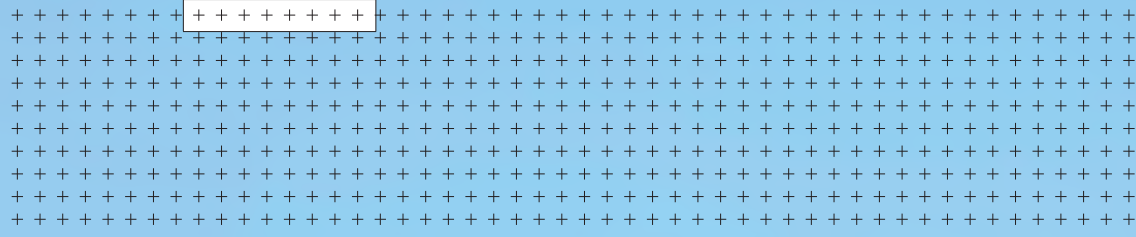
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Harmonic mitigation sets the transformer industry up for success as EV charging accelerates

by **Seth Johnson**





When the U.S. government announced a commitment to install 500,000 public EV charging stations by 2030 as part of the 2022 Infrastructure Bill, the news certainly piqued the interest of EV drivers and those considering EV adoption. There's no question the utility industry and electrical engineers responsible for system health have a keen interest in this development as well.

However, it's still very early in the plan, and so far, there's no single entity responsible for implementing it. Building out EV charging infrastructure of this scale will require collaboration from many stakeholders – from power system equipment manufacturers to property owners, local governments, building managers and network providers. Many experts, including electrical engineers responsible for power distribution, may not become part of an EV charging station project until it is well under way.



Seth Johnson is Vice President and General Manager of Powerside, a company that specializes in optimizing power quality for Utilities and C&I markets worldwide.

This wait-and-see approach could put all stakeholders a step behind when it comes to addressing a major infrastructure requirement: EV charging system reliability. For the transformer industry in particular, now is the time to start investigating how EV charging and other nonlinear loads affect power quality, transformer performance, and overall power system intergrity.

Building out EV charging infrastructure of this scale will require collaboration from many stakeholders – from power system equipment manufacturers to property owners, local governments, building managers and network providers.

Transformer specialists should plan ahead for harmonics.

EV charging, in particular DC fast chargers, rely on inverter-based resources to convert power from AC to DC. These inverters consume current differently from the voltage waveform supplied. This is referred to as a nonlinear load, which creates power quality anomalies – most notably current distortion known as harmonics. With a high percentage of total load being nonlinear, the current distortion starts to affect the voltage source, often significantly. These distortions not only disrupt charging equipment (a reliability nightmare for drivers), but they also damage connected equipment including transformers.

While the EV charging load may not be excessive, the harmonics produced during charging could lead to an overload situation that heats up the core of the transformer, resulting in premature equipment failure. One study of EV charging installation scenarios noted that a transformer feeding highly distorted current may need to be derated by up to 50%. [1] Given that charging equipment uptime is a prerequisite of publicly funded EV charging infrastructure projects, [2] an offline station represents financial loss,

commercial impact to the charging network operator, and negative user experiences.

While the EV charging load may not be excessive, the harmonics produced during charging could lead to an overload situation that heats up the core of the transformer, resulting in premature equipment failure.

There are compliance risks as well.

Even if equipment isn't damaged by harmonics, high harmonic levels are unavoidable with DC fast charging applications. Utilities may penalize power system asset owners that don't adhere to IEEE Standard 519-2022, *Harmonic Control In Electric Power Systems*. This standard limits the amount of harmonic distortion allowed in the power system, notably the point of common coupling where the client infrastructure connects to the grid. (See Tables 1 and 2 for maximum voltage distortion and current distortion limits.)

A utility has the right to shut down any facility that exceeds IEEE 519-2022 thresholds, due to the potential risk to the grid, and that includes EV charging stations. It's difficult to determine whether utilities will have

the scale to monitor these limits site by site as the charging network grows. That said, compliance with IEEE 519-2022 will need to be proven at the permitting stage, so engineers must take this into account early on.

Renewable energy sources increase the potential for high harmonics.

Efforts to develop cleaner transportation go hand in hand with the appetite for green energy. It's only natural that industry analysts and policymakers envision a significant portion of EV charging to be powered by renewable energy sources, delivered through microgrids. This model will likely be an attractive way to bring EV charging to rural and less-developed areas.

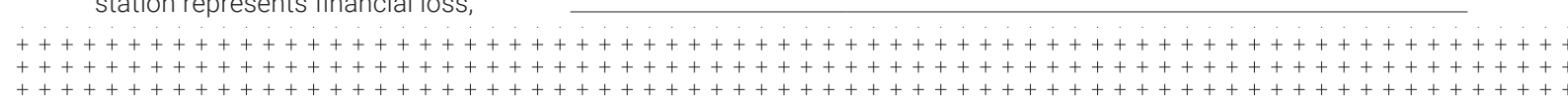
The problem: Like EV chargers, microgrids also rely on inverter-based resources to create an alternating current waveform and are subject to generating harmonic distortion.

In other words, harmonics can, concurrently, represent both a load issue and a generation issue. This recently became apparent in a "perfect storm" of EV charging interruption at a high-traffic fast charging station in California. In this case, both the chargers and nearby solar energy farms contributed to total harmonic distortion (THDv) of over 13%. (To resolve the issue,

Table 1: IEEE 519-2022 voltage distortion limits for systems rated 120 V through 69 kV

Bus voltage V at PCC	Individual harmonic (%)	Total harmonic distortion THD (%)
V ≤ 1.0 kV	5.0	8.0
1kV < V ≤ 69 kV	3.0	5.0
69 kV < V ≤ 161 kV	1.5	2.5
161 kV < V	1.0	1.5 ^a

^aHigh-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.



Powerside implemented an onsite, low-voltage active harmonic filter, configured specifically for mitigating both grid and load distortion. The result was a THDv below 3% - well within IEE 519-2022 limits.)

Meanwhile, in Virginia, one large power system routinely experienced transformer failures due to harmonics generated from a 2.5 GW solar array. EV charging was not involved, but the situation reinforces the importance of taking proactive measures to minimize harmonics for both generation and consumption of electricity.

Researchers who modeled Level 2 and Level 3 EV chargers within the IEEE 13 node test feeder encountered transformer I²R losses due to higher-order currents in transformer windings. This potentially leads to higher real power consumption; reduced efficiency; and equipment degradation due to high temperature increase. [3]

Proactive power quality monitoring paired with harmonic filtering will be essential to successful EV charging implementation.

Power quality monitoring devices can be attached to EV chargers and medium voltage power distribution to identify, measure and record data relevant to system reliability and component health. Ideally, these devices should provide data visualizations of voltage and current disturbances, harmonics, impulses, frequency variations, interruptions and overloads specific to each unit. Managers can keep tabs on these measurements remotely via desktop or mobile device, and collect the unit data from all chargers into safe cloud-based platform for fleetwide analysis, custom reporting and sharing.

When harmonic disturbances exceed IEEE 519-2022 limits or manifest

as equipment malfunction, active harmonic filtering can be applied onsite. These filters automatically inject equal harmonic frequencies at 180-degree phase shift to immediately cancel out the distortion. (In fact, this is how Powerside resolved the fast charging EV station failure mentioned previously.) Active filters are preferred over passive filters for this application because they adapt to changing harmonic influence (typical with stochastic EV charging patterns) and simultaneously filter out several harmonic frequencies from a distorted voltage waveform coming from the grid.

Knowledge is power. Collectively, stakeholders all along the grid have a role in grid resilience.

Assuming the U.S. EV charging infrastructure plan fully comes to fruition, experts say it will represent the most significant new load and revenue source for utilities in decades. [4] While many observers worry that demand will exceed generation capacity, the reality is that advances in energy efficiency have led to decreased power consumption. The U.S. grid remains relatively robust.

Table 2: IEEE 519-2022 current distortion limits for systems rated 120 V through 69 kV

Maximum harmonic current distortion in percent of I_L

Individual harmonic order (odd harmonics)^{a,b}

I_{SC} / I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	TDD
<20 ^c	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10.0	4.5	4.0	1.5	0.7	12.0
100 < 1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

^aEven harmonics are limited to 25% of the odd harmonic limits above.

^bCurrent distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

^cAll power generation equipment is limited to these values of current distortion, regardless of actual I_{SC} / I_L where:

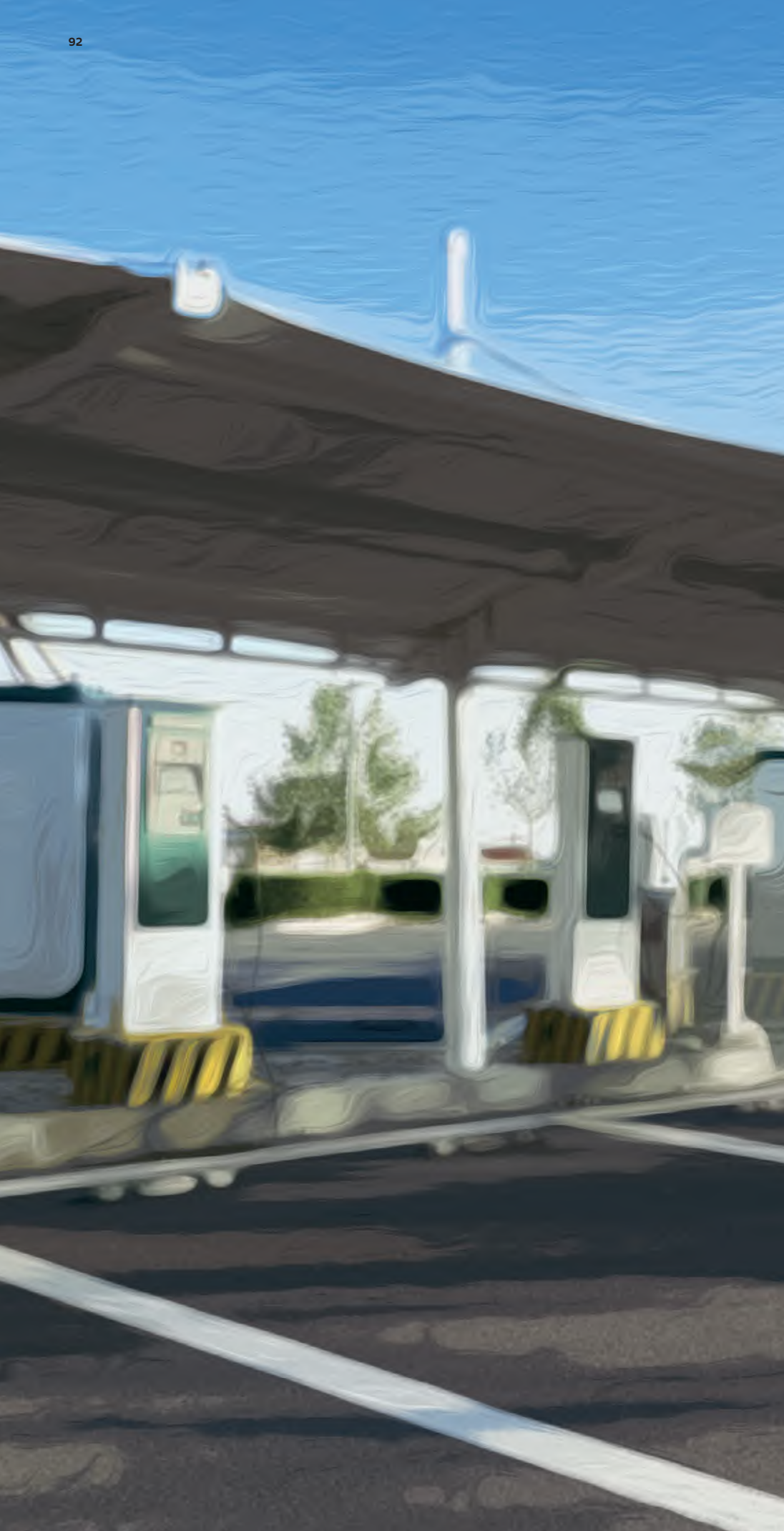
I_{SC} = maximum short-circuit current at PCC

I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

Assuming the U.S. EV charging infrastructure plan fully comes to fruition, experts say it will represent the most significant new load and revenue source for utilities in decades.

However, harmonics will continue to be a concern due to its effects on reliability, equipment life and grid stability. As the use of EV chargers, microgrids, power electronics and other harmonics-producing technologies increases, stakeholders on all sides of the meter — charging station networks, utilities, equipment manufacturers, engineers and specifiers — all have a part to play.

Increased rollouts of thorough power monitoring will allow operators to quickly react to rising EV charger failure rates with data-driven assessment of solutions and mitigation strategies to keep our grid secure.



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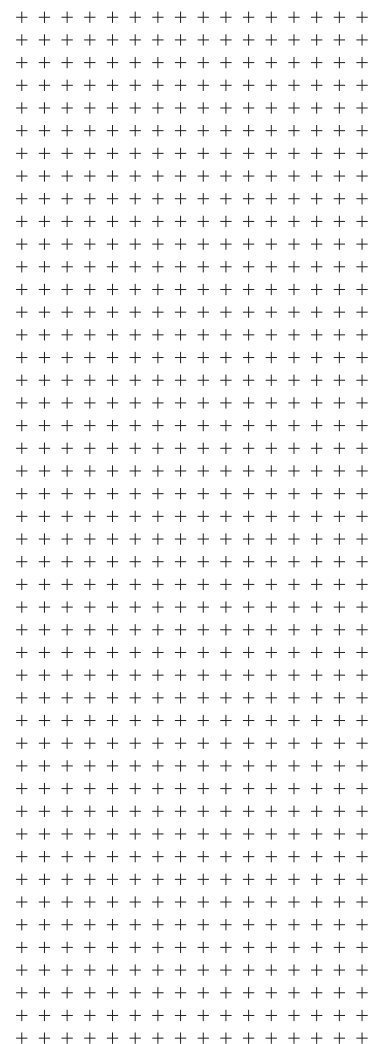


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BUSHINGS & COMPONENTS: LTCs, GAUGES, CONTROLLERS...

In October we focus on Bushings & Components (LTCs, Gauges, Controllers). It is one of our annual favorite issues and we have added new advances in other transformer components like LTCs and controllers.

In our October edition, we explore the **critical role** that **transformer bushings** and components play in ensuring the efficient and reliable operation of power systems.

From their vital function in **electrical insulation** and **support** to their impact on the overall **performance** and **longevity** of transformers, we **unravel** the **complexities** surrounding bushings and components.

Bushing technology is also adapting to new demands with new materials and manufacturing processes that the professional engineer must keep track of, so while much of the editorial space is spoken for, if you have an article, perspective or interview you would like to submit, please reach out to me at alan.ross@apc.media as soon as possible. We will be closing editorial content soon.

COMING IN OCTOBER ISSUE