ISSUE 23
November 2022 transformer-technology.com ISSN 2642-2689

POWER SYSTEMS TECHNOLOGY

# PST POWER SYSTEMS TECHNOLOGY


# SOLID STATE REVOLUTION

TRANSFORMER TECHNOLOGY MAG

TRANSFORMER TECHNOLOGY MAG

Grid Storage: **A New Paradigm for Solid-State Batteries**
Interview with **Dr. Bahadir Basdere**, President of Trench Group
**Hydrogen Management in Battery Rooms**

TRANCO

AT THE CORE OF YOUR BUSINESS

# Celebrating more than 48 years
## in core-winding solutions

### Our Mission

To provide the transformer manufacturing industry with **top-quality, Canadian-made core-winding machines** that help their operations to run smoothly, and tailored service plans to maintain that standard.

We pledge to work with our clients to understand their unique needs and provide innovative solutions, because our commitment to reliability is lifelong.

For more information on **TRANCO** core winding machines, visit our web site at **www.tranco.ca** and contact us at **sales@tranco.ca** or by phone at **+1 905 669-4840**.

# GET CLOSER
## TO YOUR CUSTOMERS

YOU HAVE A GREAT PRODUCT.
WE HAVE GREAT CONNECTIONS.

LET US BE THE LINK.

TRANSFORMER TECHNOLOGY COMM

## LET'S GROW YOUR BRAND TOGETHER

### CONTACT OUR TEAM

**North America** Rachel.Linke@apc.media
**Global** Marin.Dugandzic@apc.media

*Photo: Mike van Schoonderwalt from Pexels*

# Contents

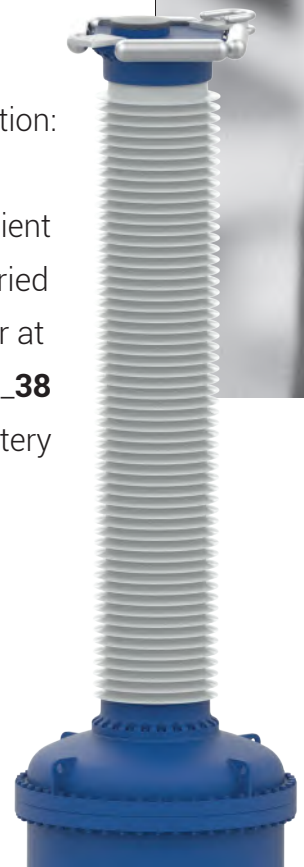
Table of

# Index



**16**

Interview with
Dr. **Bahadir Basdere**,
President of Trench Group







# Contents

# Index



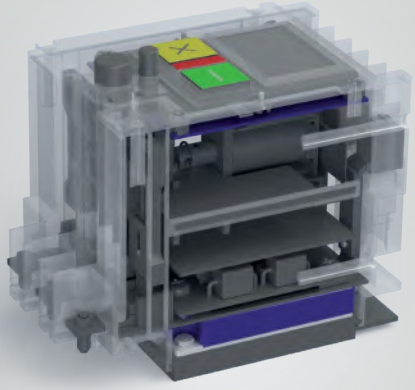
Table of

**52**

WPS Interview with **Sabine Bowers**, Power Systems Global Renewable Energy Leader for Cargill Bioindustrial









# EVERYONE YOUR PRODUCT MATTERS TO IS HERE

WITH 10,000+ MEMBERS AND VISIBILITY TO 100,000+ SOCIAL MEDIA FOLLOWERS

WE HAVE AN OUTSTANDING REACH TO YOUR TARGET AUDIENCE.

TRANSFORMER TECHNOLOGY COMM

## WHAT IS YOUR REACH? EXPAND IT. ADVERTIZE WITH TT.

### CONTACT OUR TEAM

**North America** Rachel.Linke@apc.media
**Global** Marin.Dugandzic@apc.media

Photo: Shutterstock

A BETTER ENERGY FUTURE IS A FUTURE OF COLLABORATION

# Inspire. Empower. Advocate.

## WPS Women in Power Systems

**Women in Power Systems (WPS)** is a community that advocates for women in all power systems roles, celebrates their successes and helps them achieve a balance between their professional and private life.

**Become a Sponsor of Women in Power Systems and bring positive change to your company and the industry.**

- Be a thought leader
- Benefit from female talent in diverse roles and build a collaborative workforce
- Position your company as a socially aware and desirable employer
- Get promoted through WPS social media campaigns
- Reach over 100,000 industry professionals through WPS Alliance Partners' platforms

Find out more about **WPS Sponsorship opportunities** here.

Check out the **WPS Community Hub** for stories, news and more here.

WPS Alliance Partners

TRANSFORMER TECHNOLOGY COMM · epra · THE ELECTRICITY FORUM · energycentral. · CWIEME GLOBAL


# WATCH & LISTEN

## TECH TALKS AND PODCASTS

*with Alan Ross*

TRANSFORMER TECHNOLOGY COMM

## READY TO HEAR MORE?

### VISIT OUR CHANNELS

**TT Web** transformer-technology.com
**TT YouTube** youtube.com

TRANSFORMER
COMPANY
YELLOW PAGES

# LIST
# YOUR COMPANY

## IN THE ONLY
## TRANSFORMER COMPANY YELLOW PAGES
## IN THE INDUSTRY


TRANSFORMER
TECHNOLOGY COMM

## ASK US HOW TO LIST
## AND LEARN ABOUT THE BENEFITS

**HERE**
transformer-technology.com

Photo: Shutterstock

# Impressum

**TRANSFORMER** TECHNOLOGY MAG

**Technical Advisory Board (TAB)**
**Executive Advisors**
**Alan M. Ross**, CRL, CMRP
The Chair and Managing Editor
**Corné Dames**
Independent transformer consultant
Transfomer oils
**Ben Lanz**, IEEE PES Senior Member
Power system reliability, asset management and diagnostics

**Technical Advisory Board Members**
**Diego Robalino**, PhD, PMP
IEEE Senior Member
**Tony McGrail**
Asset management & Condition monitoring
**Edward Casserly,** PhD
Senior Scientist, Transformer oils
**Maria Lamorey**
Industrial OEM manufacturing
**Alan Sbravati**, ME, MBA
Transformer insulating materials
**Marco Tozzi**, PhD
Diagnostics and asset monitoring
**Curtus Duff**
Power transformer design
**Traci Hopkins**, IEEE Member
Transformer Condition Assessment
**Jon Trout**, PE
Electric utility
**Michael Riccio**, CRL, IRT CAT-1
Reliability, Electrical safety
**Alexander Doutrelepont**
High voltage bushings & insulators
**Ed Khan**
Power Systems, Relay protection, Training

**Graphic design**
BE Koncept Communication Boutique

**Photo Cover**
Shutterstock

**Sales & Marketing**
Rachel Linke
rachel.linke@apc.media
Kevan Sears
kevan.sears@apc.media

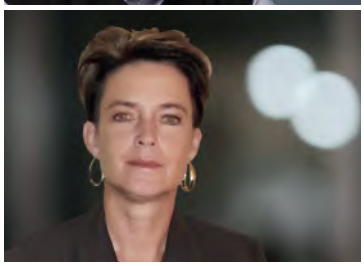
**Sales & Marketing Americas**
Jose Mora
Jose.mora@apc.media

**Sales & Marketing Mexico**
Fernando Campos
fernando.campos@transformer-technology.com

Sales **& Marketing Brazil**
Marcelo Braga
marcelo.braga@transformer-technology.com

**Marketing Global**
Marin Dugandzic
marin.dugandzic@apc.media

TAB Executive Advisor,
The Chair and Managing Editor
**Alan M. Ross**, CRL, CMRP
Transformer maintenance and reliability

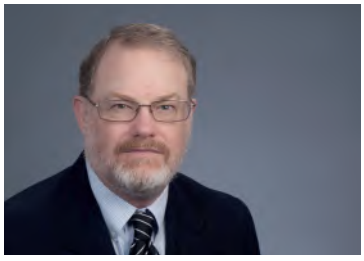


TAB Executive Advisor
**Corné Dames**
Independent transformer consultant Transformer oils

TAB Executive Advisor
**Ben Lanz**, IEEE PES Senior Member
Power system reliability, asset management and diagnostics

TAB Member
**Diego Robalino** PhD, PMP
IEEE Senior Member
Transformer condition assessment and diagnostics

TAB Member
**Tony McGrail**, PhD
Asset management & Condition monitoring



TAB Member
**Edward Casserly**, PhD
Senior Scientist,
Transformer oils

TAB Member
**Maria Lamorey**
Industrial OEM manufacturing

TAB Member
**Alan Sbravati**, ME, MBA
Transformer insulating materials

# Editors

ISSN 2642-2689 (Print)
ISSN 2642-2697 (Online)

**DIGITAL Membership**
Free

Transformer Technology magazine is a quarterly magazine published by APC MEDIA LLC, 2152 Caper Dr., Marietta, GA 30064, USA. Published content does not represent official position of APC MEDIA LLC. Responsibility for the content rests upon the authors of the articles and advertisers, and not on APC MEDIA LLC. APC MEDIA LLC maintains the right to keep the textual and graphical documents submitted for publication.

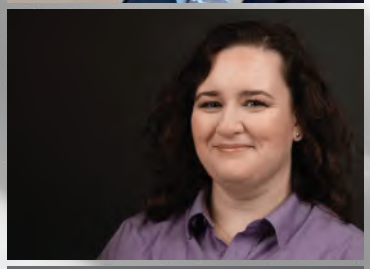


**Publisher:**
APC MEDIA LLC
2152 Caper Dr.
Marietta, GA 30064, USA

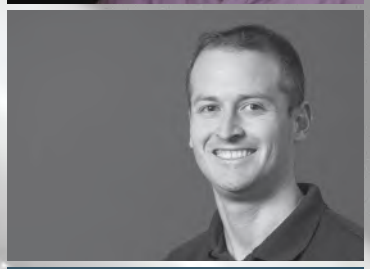
transformer-technology.com

TAB Member
**Marco Tozzi**, PhD
Diagnostics and asset monitoring

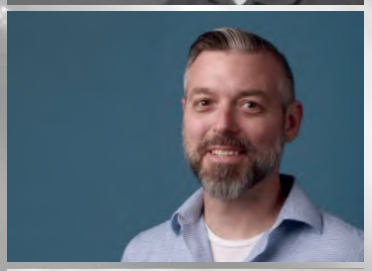
TAB Member
**Curtus Duff**
Power transformer design



TAB Member
**Traci Hopkins**
Transformer Condition Assessment

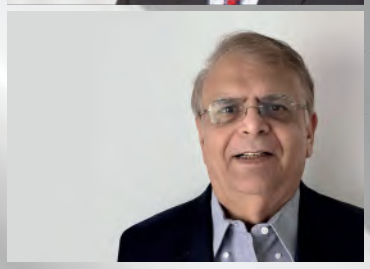


TAB Member
**Jon Trout**, PE
Electric utility



TAB Member
**Michael Riccio**, CRL, IRT CAT-1
Reliability, Electrical safety

TAB Member
**Alexander Doutrelepont**
High voltage bushings & insulators



TAB Member
**Ed Khan**
Power Systems, Relay protection, Training

**Dear Readers,**

Several years ago, in a presentation on power system reliability that I gave at the Society for Maintenance and Reliability (SMRP) annual conference, I made reference to several major changes our industry is undergoing, one of them being the move from electromechanical technology to solid state technology. This movement has been one of the reasons we wanted to grow our community by focusing on Power System Technology (PST). This issue is the big first step we are taking in this new direction.

Before we go further, know that Transformer Technology is not going away. It is just being surrounded by **Power Systems Technology (PST)**, and since the transformer is the heart of the system, it will always be an important part of PST.

Taking the new step and considering that the change to solid state technology in power systems is the biggest change taking place in the industry, we have decided to dedicate this first issue where PST takes prominence to Solid State Revolution.

Over the next few months, we will continue this publishing transition, maintaining the content that has always been a stalwart of Transformer Technology, starting with the December Issue on **Insulation, Oils & Fluids**. While fluid filled transformers are still a critical part of the power system, you will find an article from Technical Advisory Board member, Ben Lanz, reporting on technology of insulation of cables, also an important and critical asset in power. This is just to illustrate that, as we know, there can be no power system without transformers and there can be no transformers without power systems around them.

Another change you will see for 2023 is a greater emphasis on research from the power industry with a Byline from Power Technology Research (PTR), whose work in the power industry is becoming a critical resource for power professionals across the globe. We are delighted to have created a strategic alliance with PTR for content on all things power. In our December issue we will share the full plan for the themes of our 2023 editorial content, which will further illustrate the growth we are experiencing at APC Technologies. We are tremendously thankful for our staff, our contributors and especially the Technical Advisory Board, without whom we would not be able to continue to provide the amazing content with excellence.

**One of the several major changes our industry is undergoing is the move from electromechanical technology to solid state technology. This movement has been one of the reasons we wanted to grow our community by focusing on *Power System Technology (PST)*. This issue is the big first step we are taking in this new direction.**

And if you ever feel compelled to reach out to me about contributing to our themes, there are three primary ways to contribute:

- **Feature Articles** which are 1800-to-2200 word technical articles on a key topic under the themes, with a more in-depth approach.
- **Perspective Articles** which are 200-to-500 word technical articles on a single key topic that are more focused and not as much detailed as a Feature Article.
- **Interviews** which are usually created over Zoom or Teams and are published on our website, and You tube channel and are transcribed for publishing in the digital magazine.

So, let's focus on the issue before us, with great interviews from Sabine Bowers of Cargill, Dr. Bahadir Basdere of Trench Group, and the second part of the interview with Wilfred Breuer of MR. If you missed the first part of the interview, you can find it archived on our website. I believe you will enjoy it.

Couple that with great Feature Articles from Maria Lamorey of PPG, Nick Schlitz of Grace Technologies, Azhar Fayyaz with the Power Technology Research contribution for their byline, Jeff Donato, arguably one of the "rock stars" of battery room safety, and many more. This issue is full of great content, either to be read now or archived for later. Also, please **feel free to post your favorites on your LinkedIn page and share with associates who might benefit from the content**.

It takes a lot of planning and excellence to create great digital content and at APC Technologies we take pride in the staff who make all this happen. Most importantly, we are thankful for our Technical Advisory Board members and for you, our community members who make this all worthwhile.

Thank you,

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

Decentralization, Decarbonization and Digitalization
**A Holistic Concept of Innovative Solutions for the Energy Transition**

# Bahadir Basdere

“

I believe that we are facing the most exciting, but also the most challenging times. However, it is a positive challenge.

**President** of Trench Group

Interview with **Dr. Bahadir Basdere**

*Photo: Trench Group*

**Transformer Technology hosted the President of Trench Group, which is composed by Trench and HSP. In this interview we talk to Dr. Bahadir Basdere about REGENERA™ initiative, because it is all about the three Ds–Decentralization, Decarbonization and Digitalization of the industry.**

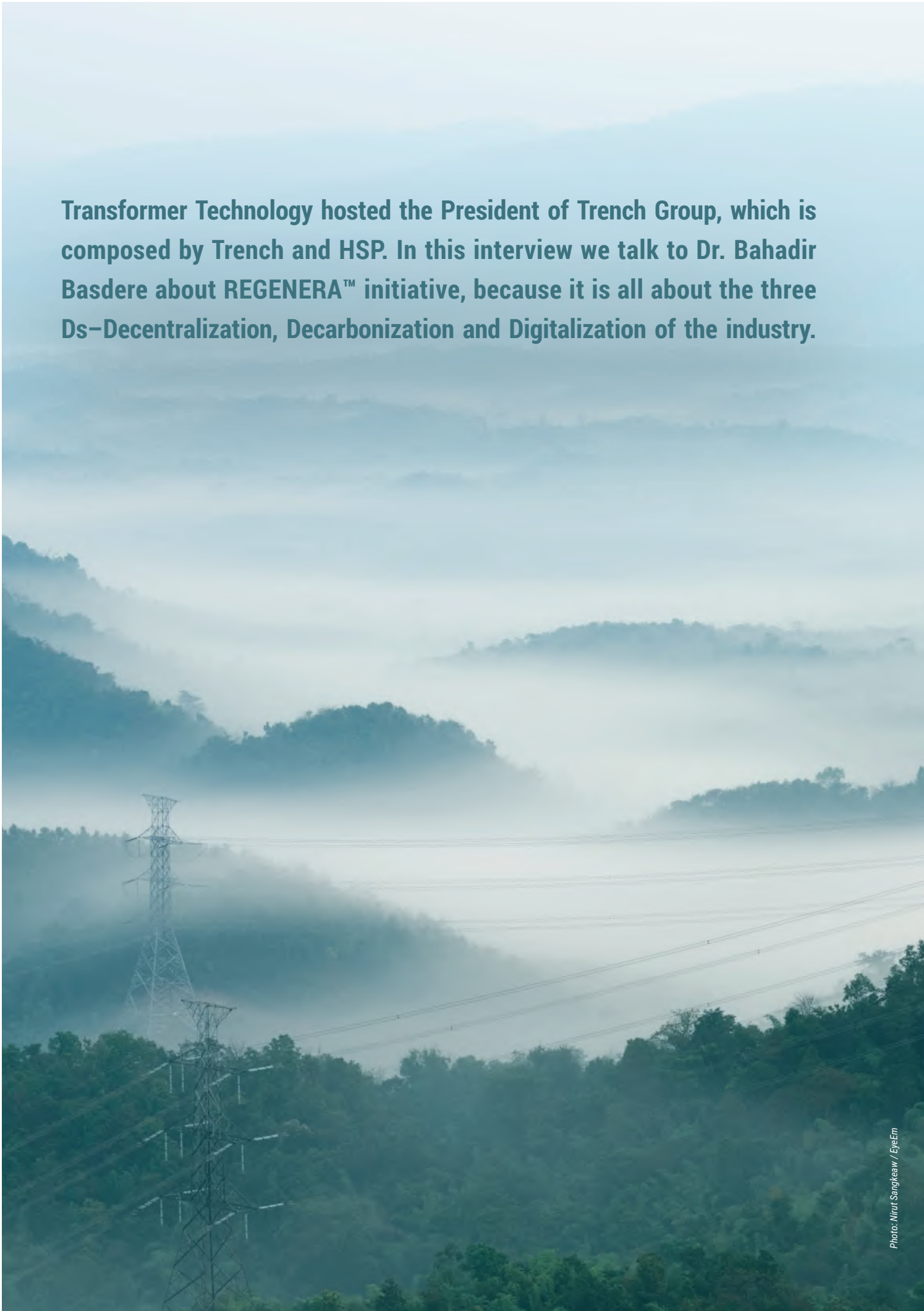


*Photo: Nirut Sangkeaw / EyeEm*

**Alan Ross:** My guest in this interview is Dr. Bahadir Basdere. What is your role at Trench & HSP?

**Bahadir Basdere:** I have two major roles. I have the role as President of Trench group, which consists of the different Trench entities around the globe, as well as HSP, our dry type bushing business. Secondly, I also represent the shareholder Siemens Energy for the entire Trench Group.

AR We're going to talk about your REGENERA™ initiative, because it is all about the three D's - Decentralization, Decarbonization and Digitalization of the industry. But before we get to that, could you talk to me about where you think we are in the power industry as a whole?

BB I believe that we are facing the most exciting, but also the most challenging times. However, I would say that it is a positive challenge. If you think back to 2008 when we had the financial crisis, or a little bit after that, we were faced with a significant decrease of demand and overcapacities in the power industry. We went through more than a decade of coping with those challenges. Now it's the total opposite. We have a HUGE demand.

I see it this way, one of the few positive effects of COVID were the financial grants for all the renewable programs the governments launched. On top of that, the political situation that we currently have in Europe, the war between Russia and Ukraine is now the booster for quickly diversifying and decentralizing power generation. Also, when we look at the biggest challenge of mankind, it is Decarbonization. And for me, these things go hand-in-hand. Digitalization is an enabler to speed up decentralisation and decarbonisation.

AR Great! So we have the three D's - Decentralization, Decarbonization and Digitalization - but also Diversification. I agree with you that these are the most challenging, but also the most exciting times.

As President of Trench Group & HSP, let's talk about the vision and the mission of the organization of which REGENERA™ is also a part. What are you trying to accomplish?

BB Our mission is to support our customers in decarbonising the world with their equipment, and with their products and projects that they acquire from us. This is a clear mission, and we have a clear target. We would like to be able to offer our customers a 100% $CO_2$ neutral portfolio by 2030. I believe we are leading the industry here when we look at our portfolio on bushings, instrument transformers and coils and specifically at the innovations that we are driving.

AR With you and I being in the power industry, we understand the challenges of reducing $CO_2$. When you look at the entire system, where are the areas that you think you could focus on, to be able to accomplish this, at least in the short-term?

BB It starts from the design. Very simple. You need to consider environmental aspects in the design phase. You reduce material and you reduce hazardous substances that do harm to the environment, such as $SF_6$ or mineral oil. Then it goes over to production, where we have a lot of initiatives to reduce our $CO_2$ footprint. For instance, we've switched to green electricity, installed PV on our factory buildings and optimized heating and lightning. These changes can significantly reduce $CO_2$ footprint, and at the same time give you a cost advantage. So, if you consume less energy, you pay less for your energy bill.

AR Everything that we do begins in the design phase. You said something that I think is very important, which is, you practice what you preach. You put solar into play.


Our $SF_6$ Free product such as Power Voltage Transformers are our innovative answer to the urgent need for "Clean air"

You began to do the very things that we ask our customers to do, which is kudos to the company for making those kinds of decisions because it leads the way. *We have to lead the way*. As you said, these are challenging times, but exciting times because there are problems we know we can solve. We know we have the time now to solve it.

I know this is a little off topic, but how has the situation between Russia and the Ukraine affected the REGENERA™ program?

BB It is a boost for us now in particular when we look at the product part of REGENERA™. For instrument transformers, we are providing the whole range of VT's and CT's up to 800 KV in $SF_6$-free insulation – I am talking about Clean Air as a gas which is in fact nitrogen. We are also providing Ester fluid solutions. Therefore, we see a huge demand. We see big TSO's in Europe really becoming active, issuing RFQs where a certain portion of their system already requires them to be free of hazardous substances.

We also have regulation by the European Union that will significantly reduce F gas in electrical high voltage products. This is a booster too, and of course being one of the few ones offering the whole bandwidth of the portfolio is nice. But this brings us to another challenge. Now, we need to have competitors in the market who are at least offering similar products as we are, so that when demand explodes, customers can have an effective risk-mitigation strategy. Understandably, they cannot be dependent on one supplier for this equipment and technology.

AR Kudos to you to see it that way; nobody can do this alone. That's the one thing that I walked away from this conference saying, there's nobody that's got the one answer.

The important thing is to develop new technologies and new approaches. So, for instance, getting rid of $SF_6$ gas, that's an industry-wide problem that needs an industry-wide answer. So how do you share technology with your peer competitors, without sharing your secrets to success?

*Photo: Trench Group; Freepik*

BB Great question, and I really do see them as peers because no one is able to serve this huge market alone. To answer your question, I must highlight that we do not share our technology. However, we do have exchanges with our peers on a regular basis on topics like industry standards or what is needed to foster green technology. In general, I would say it is an exchange on a higher, technical level.

You may even see partnerships in the industry. We've seen that happen. I think it's absolutely important that this *exchange* with peers takes place to make sure that we go in the right direction. Because at the end of the day, what we need is speed and as you said, we can only have speed and results if we all move in the same direction. Our customers want to have a standardized solution, and they cannot cope with multiple approaches.

AR Somebody once said, and I told the person that said this that I was going to steal it, and I'm stealing it now. If you want to go fast, go alone. If you want to go far, go together.

BB That's right.

AR What we have to do now is unbelievable. We have to go far, fast. We must get there a lot quicker.

You mentioned something I want to go back to. You have all these initiatives, but you have a lot of suppliers. I mean, you don't magically make bushings and instrument transformers. You bring all these suppliers in. Are you putting in place supplier covenants that ensure that your suppliers are also managing the four D's? Particularly Decarbonization. Is that something that you're bringing them along with? Because that's going far and it's going fast.

BB Absolutely, Alan, and on that point: we have started doing Lifecycle Assessments for our products, which is a very important tool. It is where we consider the $CO_2$ footprint of our suppliers, of the components being supplied. We also audit them on environmental aspects which is a clear focus of ours. It is our aim to incorporate the results of lifecycle assessments also in the new development phase of future products and solutions.

AR I would have to say that bushings are a major component of transformers. I think recent research that I read was that 52% of transformer failures were bushing failures. Nine times out of ten, it is due to aging.

However, it is safe to say that bushing technology is changing rapidly. How are you all advancing bushing technology as part of this whole REGENERA™ initiative?

BB In bushings we have to distinguish between oil- and resin impregnated bushings. On the oil immersed bushings side, we are fostering the shift to ester fluids instead of mineral oil. This not only has a positive contribution to the environment, it also comes with significant technical advantages on aging and safety, e.g., the higher flame point of ester fluids is reducing the risk of fire hazards substantially.

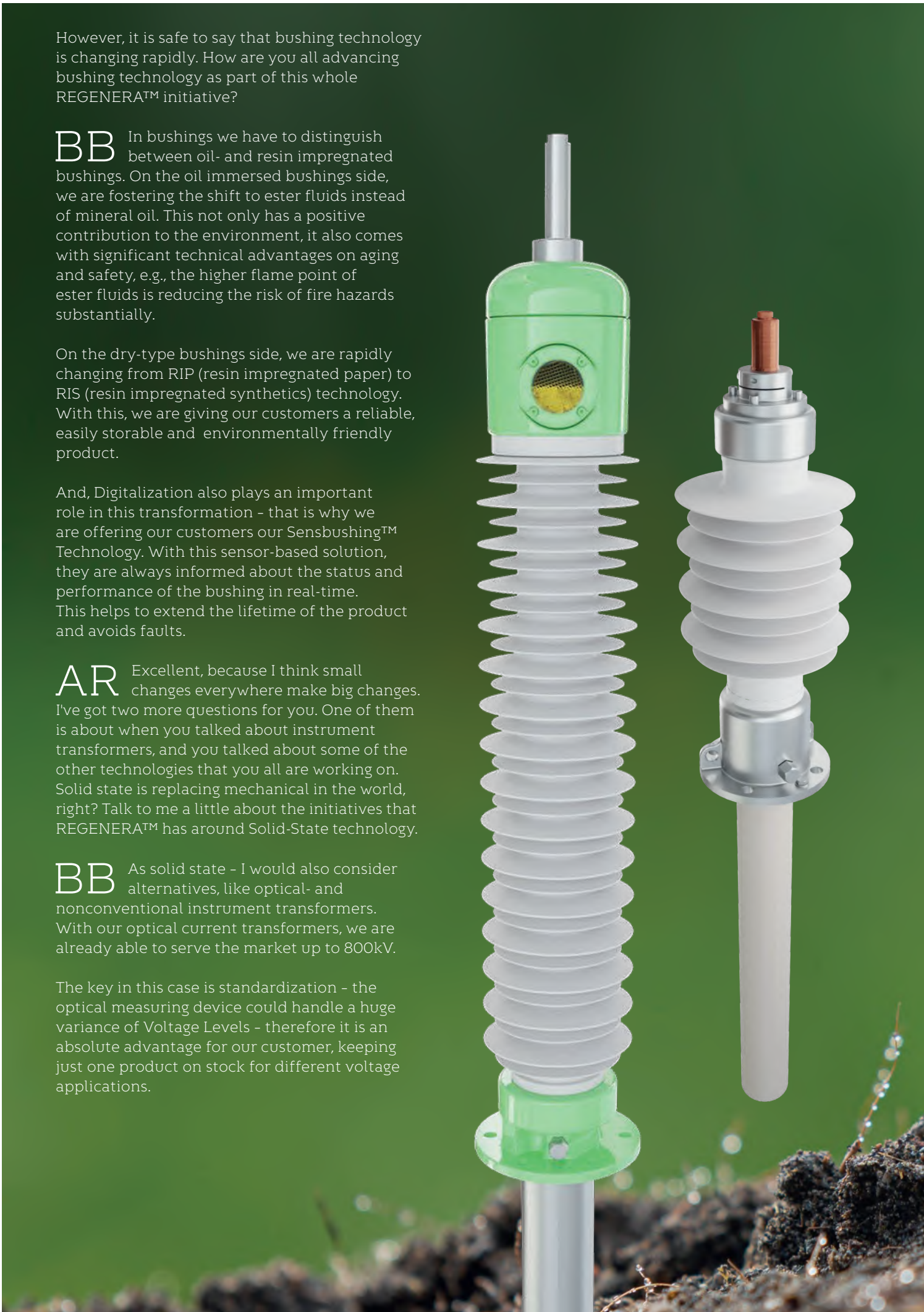
On the dry-type bushings side, we are rapidly changing from RIP (resin impregnated paper) to RIS (resin impregnated synthetics) technology. With this, we are giving our customers a reliable, easily storable and environmentally friendly product.

And, Digitalization also plays an important role in this transformation - that is why we are offering our customers our Sensbushing™ Technology. With this sensor-based solution, they are always informed about the status and performance of the bushing in real-time. This helps to extend the lifetime of the product and avoids faults.

AR Excellent, because I think small changes everywhere make big changes. I've got two more questions for you. One of them is about when you talked about instrument transformers, and you talked about some of the other technologies that you all are working on. Solid state is replacing mechanical in the world, right? Talk to me a little about the initiatives that REGENERA™ has around Solid-State technology.

BB As solid state - I would also consider alternatives, like optical- and nonconventional instrument transformers. With our optical current transformers, we are already able to serve the market up to 800kV.

The key in this case is standardization - the optical measuring device could handle a huge variance of Voltage Levels - therefore it is an absolute advantage for our customer, keeping just one product on stock for different voltage applications.



Beside this and other benefits, the digital system can measure network information that can currently only be collected with additional effort. Things are moving fast now, and we see very positive response from our customers.

AR My last question for you which you've kind of answered already. You launched REGENERA™, and you created this initiative around the four D's. My question then is how do you get the entire company to get excited about this?

BB Trench and HSP are brands with deep roots. E.g., Tony Trench built the first coil in 1962, and over the years Trench has been acquiring companies that have been in this industry for more than 100 years. Employees and customers alike have a very strong bond with these brands. Some of our people have been working for us for over 50 years but we also attach great importance to bringing new energy to the company and therefore we invest in human resources. With this in mind, we have recently repositioned both brands and redefined our vision, mission, and values to give them an experience-based and strongly future-oriented perspective, each according to their own strengths.

Our team is completely behind us on this, and we did not face a lot of reluctance with our employees because they see it as a chance for change and a way to be involved in our transition to a greener future.

AR Thank you so much for this interview, and I really love what you're doing at Trench Group.

BB Thank you.

> “Together, we have developed sustainable and reliable Bushing solutions for an eco-friendly life cycle

Photo: Trench Group, Freepik

# Grid Storage: A New Paradigm for Solid-State Batteries


by **Denis Phares**



First it was power tools and laptops, then smartphones, and now electric vehicles. Lithium-ion batteries have revolutionized how we live our lives. They've given us freedom and flexibility and have completely changed the way we look at power.

*Lithium-ion batteries have revolutionized how we live our lives. They've given us freedom and flexibility and have completely changed the way we look at power.*

Of course, the rise in gas prices and the shift to look toward a greener future have played an integral part, but what has really been at the epicenter of the switch from gas guzzlers to electric vehicles is the advancements in Li-ion battery technology. At the end of last year, there were approximately 16.5 million electric cars on the road.

Dr. **Denis Phares** received a B.S. in Physics from Villanova University, an M.S. and Ph.D. in Environmental Engineering Science from California Institute of Technology, and an MBA from the University of Nevada, Reno. After establishing himself as a tenured professor of Aerospace & Mechanical Engineering at the University of Southern California, Phares left academia to found Dragonfly Energy in 2012. With three decades of extensive experience in the fields of Energy, Nanotechnology, Fluid Mechanics, and Powder Processing, Phares has positioned himself as a leading expert in green energy storage and has spent the last 15 years focused on advancing lithium-ion battery technology. He holds a number of patents, some of which are key in fundamental battery cell manufacturing. Dr. Denis Phares is the President and Chief Executive Officer of Dragonfly Energy Corp., where he focuses on developing technologies aimed to change the way we store and harness renewable energy.

*Photo: DragonFly Energy*

That's triple the amount as of 2018, and nearly 10% of the total cars that were sold worldwide in 2021. There's been a significant shift in this world of transportation, thanks to this battery technology.

While the portability and flexibility of powerful lithium-ion batteries, whether it be in an EV or a cell phone, has facilitated the technology on which we have relied over the last decade, it's also no secret that Li-ion batteries have earned their fair share of a bad reputation.

LG, one of the world's largest lithium-ion battery manufacturers, recalled its home storage solution. In China, a lithium iron phosphate storage system caught fire in Beijing and killed two fire fighters. GM recalled 142,000 of its Chevy Bolts because of risk of fire. The flammability of these types of batteries is a huge pain point, one that needs to be addressed and solved, especially for specific applications, like residential energy storage, for example.

So that leads us to the question: Can they be made better? Can Li-ion batteries be made lighter? Safer? Non-flammable? More powerful? And longer lasting? The answer is: probably. But not all at once. The metrics to optimize really depend on the desired application. From electric vehicles to deep cycle grid storage, there is no one Li-ion battery solution.

*Can Li-ion batteries be made better? Lighter? Safer? Non-flammable? More powerful? And longer lasting? The answer is: probably. But not all at once. From electric vehicles to deep cycle grid storage, there is no one Li-ion battery solution.*

## Li-ion Battery Basics

To start with the fundamentals, there are a number of elements inside a Li-ion battery cell that are ripe for innovation. Each of those elements represents an active area of research, both at research labs globally and among large and small battery companies looking for an advantage—looking for a way to take the capabilities of Li-ion batteries to the next level and to undiscovered markets.

But no matter the elements it's comprised of, every Li-ion battery works in the same fundamental way. Here's how.

A lithium-ion battery is an electro-chemical cell that consists of a cathode as the positive side, an anode as the negative side, a separator, and an electrolyte in the middle.

The cathode typically consists of a lithium-containing compound, either in the form if a lithium metal oxide or a lithium metal phosphate.

*A lithium-ion battery is an electrochemical cell that consists of a cathode as the positive side, an anode as the negative side, a separator, and an electrolyte in the middle.*

Phosphates tend to be heavier, but safer and longer lasting, while oxides tend to be lighter but more volatile. Most of the successfully deployed technological improvements have focused on the lighter oxide chemistries, including those that contain Nickel, Cobalt and Aluminum (NCA) or Nickel, Cobalt and Manganese (NCM).

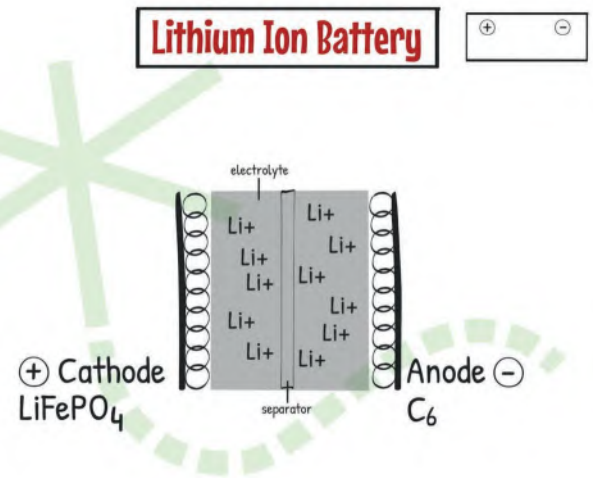
Now, on the negative side of the battery, you have the anode, typically comprised of graphite. As the battery charges, lithium ions insert themselves into the graphite particles in a process known as intercalation.

When it comes to looking to develop a lighter-weight battery, graphite is the next target for replacement as it tends to be a fairly heavy material and replaceable.

Gaining great traction commercially as an alternative to its heavier counterpart is silicon.

While silicon has its benefits, the true gamechanger is a pure lithium metal anode. Using pure lithium metal as the anode requires no intercalation at all. Instead, lithium ions become lithium metal in a process that may not even require a host material, and this means that the battery can be made to be much lighter.

Moreover, without needing to rely on the intercalation process when using lithium metal or a host material to hold lithium ions on the anode, a battery with a lithium metal anode can also be charged much faster. This seems like the ultimate solution. Lighter-weight and faster charging—the perfect Li-ion battery.




***A lithium-ion battery** is an electrochemical cell that consists of a cathode as the positive side, an anode as the negative side, a separator, and an electrolyte in the middle.*

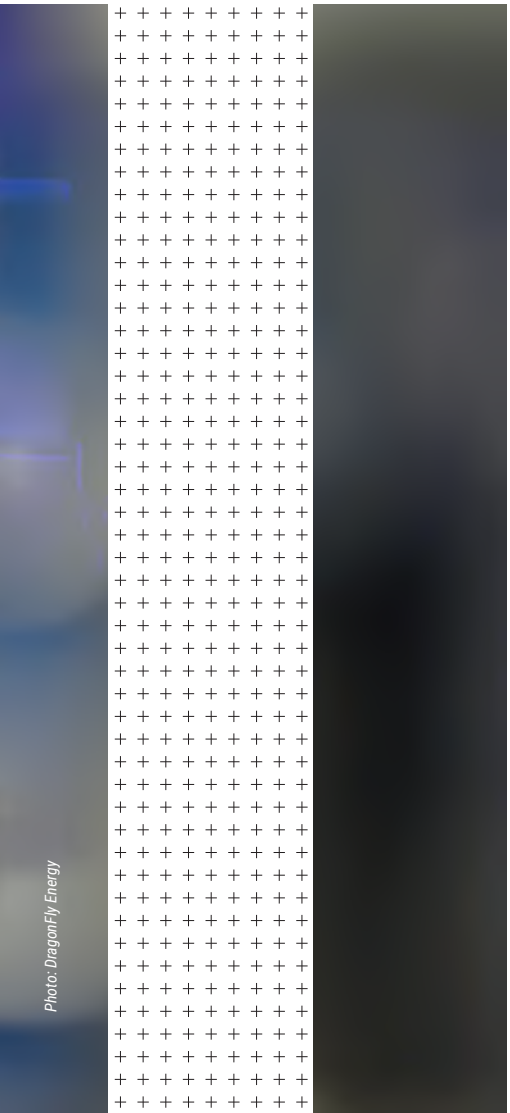
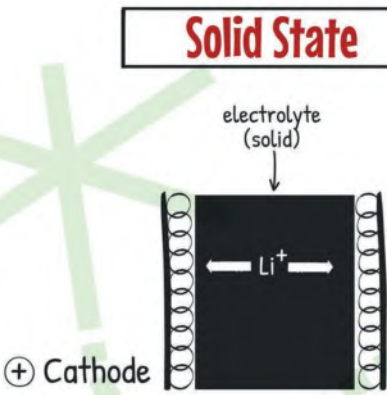


Photo: DragonFly Energy




***A solid state battery** uses a lithium metal anode and a solid electrolyte.*

But there still remains a problem. With this type of anode, the lithium metal forms as whiskers, called dendrites, as it plates onto the anode. These lithium metal dendrites have a higher chance of short circuiting the battery internally, potentially causing a fire.

This risk of fire brings us to analyze another component of the battery called the electrolyte—that material located throughout the cell that serves as a conduit through which the lithium ions move between the anode and the cathode. In a conventional lithium-ion cell, this electrolyte is a liquid—a highly flammable liquid, again, posing a risk for an unsafe solution.

So what is that next alternative material to replace an unsafe liquid electrolyte? A solid.

## An All-Solid-State Solution

What many consider to be the next major innovation in lithium-ion battery technology is the move from a liquid to a solid—to replace that liquid electrolyte with a solid material that can also serve as an efficient conduit for lithium ions.

When a solid electrolyte is placed between the anode and the cathode, that solid becomes the separator, can block the formation of dendrites in the case that the anode is lithium metal, and allows for lithium ions to travel back and forth between the anode and the cathode, all factors making it a much safer and non-flammable alternative.

And although the electrolyte itself does not do much in terms of changing the weight of the battery, it allows for the possibility of a battery that is not dangerous and still has that lithium metal anode—a light and fast charging battery.

When it comes to deciding on a material for that solid electrolyte, there are options, each ideal for different applications, from electric vehicles to grid storage.

## The Ideal EV Battery

For years, the two most significant "pain points" for electric vehicles have been range anxiety and charge time, and innovation in EV battery technology is generally focused around these two concerns.

The battery that can solve both of these? A solid state battery—one that uses a lithium metal anode and a solid electrolyte. But certain issues remain before the commercialization of electric vehicle batteries having a solid electrolyte can come to fruition. Why?

Well, one significant issue is how a solid electrolyte, so perfect that it can block the growth of submicrometer dendrites, has not yet been mass produced in a cost-effective way. Another issue is the interface between the solid electrolyte and the anode or the cathode, which are also solid. This interface is not a problem if the electrolyte is a liquid.

So how do we solve the issue? We could fill the cell with a liquid or gel electrolyte in addition to the solid electrolyte. But in this case, the battery is no longer an All-Solid-State-Battery (ASSB), and flammability is

reintroduced. Now you see why the race to create and then mass produce the perfect solid-state EV battery is still underway.

## The Proliferation of EVs

It's important to be clear that a perfect solid-state lithium-ion battery has not been required for the EV revolution to occur. And that's been exactly the case for electric vehicle and lithium-ion battery manufacturers since EVs were introduced, which is great news for efficiency and clean air initiatives.

But ultimately, there is still a problem with this revolution. It's not about the batteries at this point, it's about how they're charged. The majority of the energy that is filling batteries in every electric vehicle, solid state technology or not, is coming from burning fossil fuels—predominately how electricity is produced for the electrical grid. When EV owners park their car for the day or make the pitstop on a long road trip, they plug in that vehicle to charge—they plug it into a charging system that's tied to the grid, directly tied to burning more fossil fuels. Now isn't that counterintuitive?

To reduce our reliance on burning fossil fuels for energy, it is important to incorporate more renewable sources of electricity, like solar and wind—but these sources are intermittent.

There is a solution, and it brings us back to batteries. The grid needs more batteries to create an energy buffer to absorb the intermittent nature of solar and wind. And this grid-tied battery for storage is different than what exists in storage today, it's different than a traditional EV lithium-ion battery, and it's different than that ideal solid-state EV battery we talked about.

## A New Focus on Solid State: The Ideal Grid Storage Battery

Suppose most of the electricity on the grid were produced from intermittent sources like solar and wind. Expect that every light you switch on inside your home and each time you charge your electric vehicle, you're utilizing renewable energy. And consider that having a large battery in every building, every home, and every workplace is critical to making this possible.

*Solid State Research & Development Lab*

*The solid-state battery race has solely focused on the EV market from the very beginning, but that's not where the participation is here.*

*This is clearly not an ideal Li-ion solution for an electric vehicle, but it is the solid-state battery that solves grid storage and ultimately dovetails with onset of electric vehicles to migrate our carbon footprint.*

This type of battery is much different than what's needed for electric vehicles. Range anxiety isn't an issue and there's no need for extremely fast charging. So what would this ideal grid storage battery look like?

First, it would take up little space. Granted, range anxiety is not relevant here but having half of the garage taken up by a large battery bank isn't a viable option either. So, lithium-ion technology immediately fits this bill.

Second, it has to be long-lasting and affordable enough to be widely implementable. It has to last thousands of cycles and it cannot break the bank or need to be replaced with less than a decade frequency.

Finally, this battery has to be non-flammable. Lining the wall of your garage with this type of storage or installing a huge battery bank, there is no choice other than non-flammability. And this is where a solid electrolyte comes in.

This solution is a true All-Solid-State lithium-ion battery that is made specifically for grid storage. Not an EV battery that charges fast and is lighter than ever, but one that is purely meant to be placed in a battery bank inside a building to store renewable energy and reduce our carbon footprint by eliminating the burning of fossil fuels.

So how is this All-Solid-State Battery made and what materials are used to do it?

Since flammability and cyclability are critical for a large grid-tied battery bank in the home, the solution relies on keeping the solid electrolyte but to scrap the lithium metal anode. Keeping the graphite anode with the intercalation mechanism instead of utilizing lithium metal creates the possibility of a long-lasting, low-cost battery.

And the technique used to keep this type of battery low-cost? A patented manufacturing process. Using a dry powder coating process, the method works with an aerosolized dry powder that's composed of both the binder and the electrode material to dry coat the foil, leaving you with an electrode that's ready for assembly into a cell without the long process of drying. Then, a composite electrolyte is coated directly on top of the electrode.

Because a powder coating process is used, these layers are growing one particle at a time, making a very intimate, high surface area interface between the electrode and the solid electrolyte, a critical part in when it comes to the operation of the battery—getting the lithium ion out of the electrode and into the electrolyte.

This process is groundbreaking and different than anything solid-state has ever seen before, making the manufacturing high-efficient and the end product widely implementable.

*Photo: DragonFly Energy*

## The Future of ASSBs for the Grid

The electric vehicle market, batteries, renewable energy, and grid storage are all tied together in a number of ways. Non-flammability in Li-ion batteries is important—that's where solid state comes in. The look toward a greener future is on everyone's minds but burning more fossil fuels to charge electric vehicles is taking one step forward and one step back. And utilizing renewables is powerful but there is currently have no way to store that energy safely and efficiently for long-term use.

The solid-state battery race has solely focused on the EV market from the very beginning, but that's not where the participation is here. This is clearly not an ideal Li-ion solution for an electric vehicle, but it is the solid-state battery that solves grid storage and ultimately dovetails with onset of electric vehicles to migrate our carbon footprint.

*Photo: Dragonfly Energy*

dragonfly®
ENERGY

# REVOLUTIONIZING

## LITHIUM-ION TECHNOLOGY

www.dragonflyenergy.com


Dragonfly Energy is the leader in lithium-ion deep cycle batteries, making renewable energy accessible and affordable. Well-known for the consumer brand, Battle Born Batteries, Dragonfly's revolutionary, non-toxic line of $LiFePO_4$ products are displacing lead acid batteries across industries - RV, marine, material handling, off-grid applications, and more. Leading the charge in green energy storage, the future of technologies of Dragonfly Energy are working to solve intermittency today for smarter energy storage tomorrow.

LEADING THE WAY TO A

**GREENER, SUSTAINABLE FUTURE.**

# A Predictive Approach to Electrical Maintenance: Run-to-Failure versus Predicting Failure

by **Nick Schiltz**

Every facility across the globe relies on electrical power today. Most industrial and commercial facilities solely rely on their utility power feeds and transformers while other mission critical facilities depend on generators and uninterruptible power supplies for their back up power redundancy. A common factor in determining the reliability and uptime of an electrical system is the condition and the availability of the power distribution equipment such as medium voltage and low voltage switchgear, transfer switches and MCCs used in the downstream. Historically, all preventive maintenance strategies have been put in place on the cable connections, joints, busbar splices and other movable parts that shows physical symptoms of major wear and tear and stress.

Photo: Shutterstock

**Nick Schiltz** is a content specialist for Grace Technologies located in Davenport, IA. The company specializes in electrical safety products and predictive maintenance solutions. During his seven years at Grace, Nick has published more than 250 articles and blog posts ranging in topics from electrical safety best practices to the future impact of IIoT in the industrial space.

*Most facility owners and operators follow either a three-year or five-year electrical maintenance routine or in many cases only react to an unplanned power outage.*

Compared to other types of rotating equipment, the power distribution equipment makes significantly less noise or no noise during their normal operation and perhaps the reason why they get less to no attention. Additionally, the availability of skilled and trained personnel to perform the maintenance related activities combined with production pressures that intervene to perform the maintenance routines make it more difficult. Most facility owners and operators follow either a three-year or five-year electrical maintenance routine or in many cases only react to an unplanned power outage.

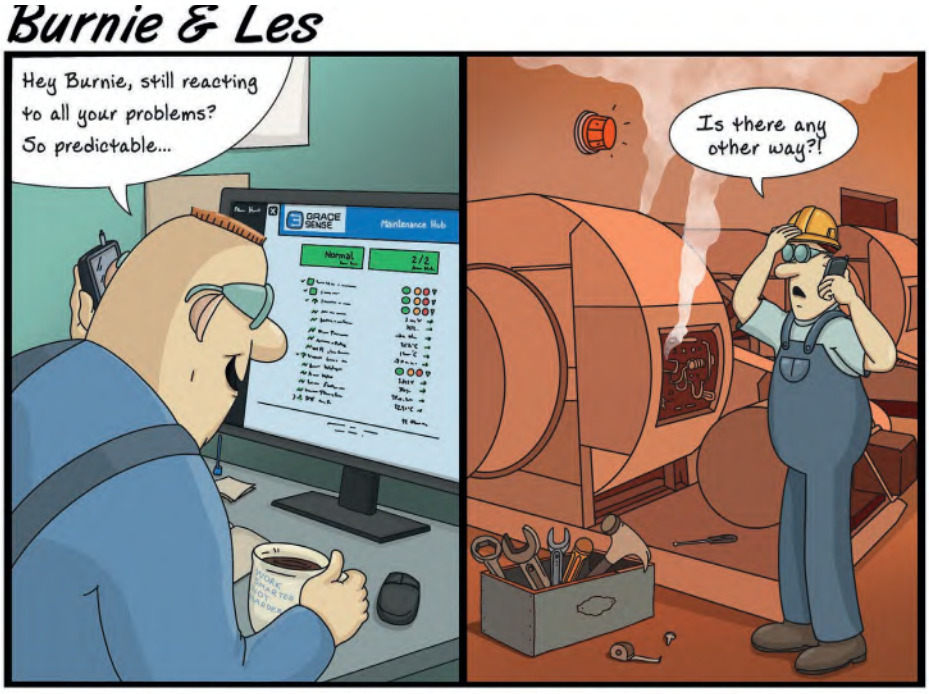
Often overlooked with the electrical power distribution equipment is the progressive addition of loads and their effect on the overall system.

For example, a system designed and commissioned with a 2000 Amps calculated load a decade ago in a collocation data center or an industrial manufacturing facility might be running well over 30-50% above the designed parameters today.

Since most systems are already designed conservatively considering the marginal future load, this may not create a major problem in the short run. However, the same trends of adding additional loads over time without considering their effects like surge characteristics and duty cycles will negatively impact the insulation and performance characteristics that could potentially lead to an unplanned outage.

## What causes your electrical equipment failure?

The percentage of total electrical failures by cause type published by a renowned industrial and facility insurance provider indicates that loose connections/parts contribute to over 30% of all electrical failures and a major cause for power outages, followed by 17% for moisture and 10.4% for line disturbance.




PREDICTIVE MAINTENANCE VS. REACTIVE MAINTENANCE

*NFPA in 2014 noted 95,700 incidents due to arcing or shorted electrical equipment, and 23,600 incidents due to overheated motor or wiring that contributed to almost one-third of all the reported incidents.*

The inconvenient truth about preventable failures of power distribution equipment is that it takes down an entire production line or in some cases the complete facility shuts down. In contrast, many processes are still operable in the event of a failure in just one single piece of downstream equipment such as a pump or motor in a manufacturing process.

Electrical system breakdowns are a leading cause of equipment and business interruption losses. It is a growing problem, and the losses can be substantial – electrical systems constitute a major percentage of a property's total value.

## Electrical maintenance prioritization: Where to start?

Electrical maintenance prioritization is one of the major concerns that many facility owners and operators encounter. In many instances, the equipment is neither brand-new nor age-old. For example, a twenty-five-year-old facility can have electrical equipment from 3 to 20 years old. How should I prioritize maintenance on my equipment?

IEEE 493 Gold Book standards paint an overall picture of how your equipment rank given the installation and reliability statistics of the various types of electrical equipment.

According to this data, many product failures occur during the infant mortality period or early-stage period because of product manufacturing defects, quality issues, followed by useful life where the failures are either stress related, human error or due to improper maintenance, and wear out failures due to aging. A simple rule of thumb is to always start with critical equipment within your facility which creates a single point failure or take the overall system down, followed by any equipment that shows impending failures. Consider the economic loss factor due to a power outage and the cost of avoidance while prioritizing your equipment.

Photo: Grace Technologies; Shutterstock

Equipment operating temperature significantly impacts the overall useful life. Most electrical systems are designed for 40°C - 45°C ambient temperature. Every 10°C rise in temperature shortens the average reliability of electrical components by 50% percent.

Thermography methods use aiming an IR Camera at the electrical connection or potential hot sources inside the electrical equipment to measure the temperature. Open door thermography inspections demand heavy PPE, certified thermographers and personnel working in the proximity of the energized components.

Closed door thermography utilizes an IR viewing window(s) installed on the equipment through which the IR camera is directed at the hot spots. It is often difficult to inspect all critical connections in an electrical panel with the IR window's limited field of view (FOV) due to the location of the window, equipment complexity, and busbar construction. Though most IR windows are available in sizes ranging from 2" – 20"diameter, larger FOV is unattainable without using bigger/more windows or highly expensive custom windows. IR windows installation in arc rated equipment further poses a threat to the arc rating of the gear, structural integrity and raises many warranty concerns over the equipment from the manufacturers.

## Routine thermography inspections

Most of the electrical equipment failures occur in power distribution equipment either due to loose connections (30.3%) or insulation failure (9.9%). While insulation breakdowns of the equipment can be identified through partial discharge surveys and tests. It is particularly difficult to identify the cause of loose connections as they could be due to both mechanical and electrical issues.

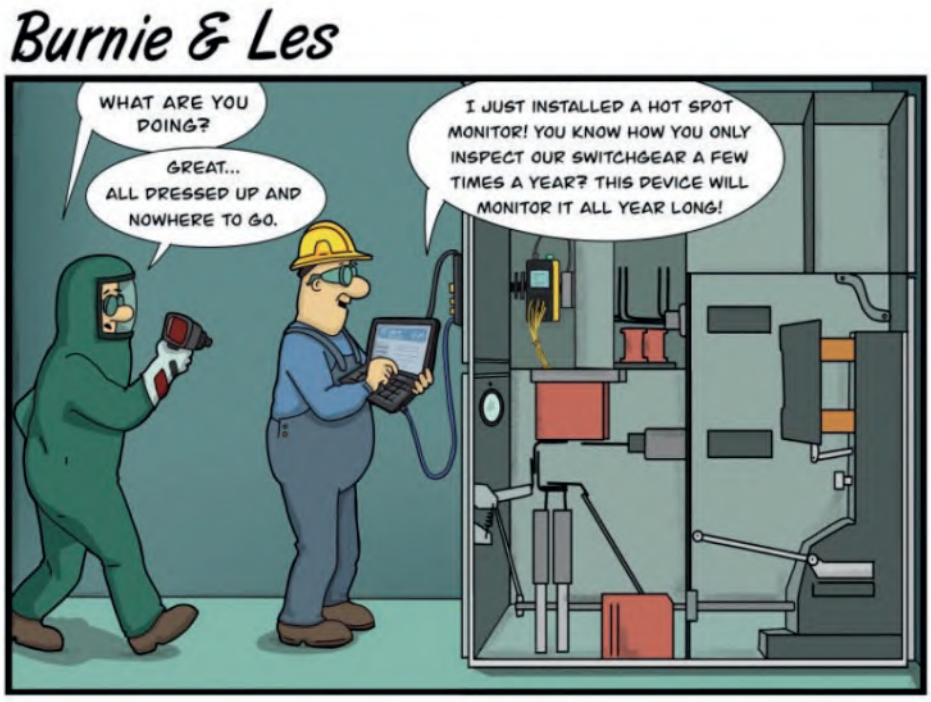
An electrical failure due to a loose connection is a current fault and it could be due to under torqued connections, mechanical load on the terminals, varying load conditions, duty cycles, cable crimping, and training. Most of these connections fail because of the excessive heat rise because of increased resistance at the connections. Both these events can be monitored without interrupting the facilities. While Infrared Thermography inspections are a most common method for predicting temperature anomalies, it is important to understand the transitivity settings of the connections monitored and proper calibrations of the Infrared (IR) Camera.

IR Thermography is a great tool to identify the temperature anomalies but requires qualified and certified thermographers to perform the work. Most insurance companies and standards require the IR inspections to be performed on systems under an energized condition that replicates the normal operating load or at least on 40% of the rated load.

Inspections performed at non-peak hours due to the facility and personnel availability also affect the relevancy of the measured data. As a result of inspections, thermographers typically issue a detailed report identifying the equipment with the corresponding image, temperature rise finding and recommended actions. Few high-end loss prevention insurance providers and thermographers provide detailed repair estimates and cost avoidance details while taking the production downtime into consideration.

7,770 structure fires. Of all the structure fires, Electrical distribution and lighting equipment were involved in 24% and heating equipment was involved in another 16% of these fires. Another report of non-fire, non-rescue electrical incident data published by NFPA in 2014 noted 95,700 incidents due to arcing or shorted electrical equipment, and 23,600 incidents due to overheated motor or wiring that contributed to almost one-third of all the reported incidents.

Avoiding a catastrophic electrical equipment failure will not only save the equipment and the downtime but can greatly help to avoid significant damages to the property and personnel. Electrical equipment failure and bearing failure that resulted in motor overheating triggered two large-loss fire incidents. The financial losses were listed as $17.6 Million and $13 Million (NFPA Large-Loss Fire Report 2016).




## Damages beyond equipment and downtime

A research report published by National Fire Protection Agency (NFPA) in 2017 noted that 37,910 fires in industrial and manufacturing properties were reported for the period 2011-2015 which included

## The predictive approach

Continuous temperature monitoring devices available on the market today can spot temperature abnormalities in electrical connections of power distribution systems such as busbars, MCCs, drive panels, switchgear, bus ducts, etc. These predictive

*Predictive maintenance smart devices will monitor, log, alarm, and enable users to trend temperature variations that are indicative of a potential fault.*

Photo: Grace Technologies; Shutterstock




maintenance smart devices will monitor, log, alarm, and enable users to trend temperature variations that are indicative of a potential fault. When integrated with a facility's electrical preventive maintenance program (EPM) as defined in NFPA 70B, these devices allow maintenance personnel to plan and schedule maintenance tasks that will avoid unplanned shutdowns and monetary damages.

Maintenance is an enforceable code under OSHA. NFPA 70E states that equipment owner shall be responsible for maintaining the equipment and documenting the maintenance records to reduce workers exposure to electrical hazards. The standards also state that the maintenance shall be performed per manufacturer recommended guidelines or industry consensus standards such as NFPA 70B, or ANSI/NETA MTS.

As referenced in Dept. Of Energy, O&M Guide, top-performing facilities utilize 45-55% predictive maintenance programs, compared to 25-35% preventive maintenance and 10% reactive or run-to-fail maintenance. While a top performing facility and an average facility both spend about the same on preventive maintenance programs, the major difference is on how they compare on the predictive and run-to-failure metrics.

# Wilfried Breuer

**Managing Director** at
Maschinenfabrik Reinhausen

Interview with **Wilfried Breuer** Part 2

“

## The challenges of renewable and distributed energy generation: Can we make it to green and sustainable, energy self-sufficient societies?

Photo: MR

**Earlier this year, we published the first part of our interview and an inspiring talk with Wilfried Breuer, the Managing Director at Maschinenfabrik Reinhausen (MR), who prior to joining MR in April of 2019, had extensive experience in the transmission and distribution world, including working for Siemens in Thailand and several other countries, and TenneT Holdings in the Netherlands, where he served on the executive leadership team. In this interview, we turn focus to the challenges of sustainability of renewable energy generation and distributed energy systems.**

Photo: iStock

**Alan Ross:** Wilfried, it's good to have you back and I look forward to continuing our interview.

**Wilfried Breuer:** Thank you, Alan.

AR I want to switch gears from what we discussed in the first part of the interview - and I invite readers to read it, it's incredible, and switch to your knowledge base which goes back to your time at the utility industry. I would like to ask you several things, but first let's talk about what is changing so rapidly all over the world now, and that is the distributed energy.

Where do you think we are going with distributed energy resources? So, the wind, the solar and the transition to becoming more green?

I think the move to wind and solar is unavoidable, not only because politicians are claiming so, but also because it is becoming much more economic, evidently cheaper and faster to implement. If you look at projects where nuclear power plants are being built or planned, many face cost overrun and are running out of schedule in Finland, in the UK, etc. They cause big political debates in society, and in a democracy, you need almost two decades of stability to see these projects going through, which is increasingly difficult. Coal in itself is also not cheap and is recognized for its harmful impact on the environment.

I think solar and wind will also dominate in the future for economic reasons, not only ecological. So, this is why I believe that this trend is unreversable and it's not going to come to a hold.

Europe is ahead of the North America in terms of green technology. So, where do you see us going and what are the challenges we are going to face?

WB The challenges, in my point of view, is clearly maintaining the same grid stability. What will be the spinning reserve in the future, and how do we stabilize the future grids?

The planet needs cheap energy for second and third-world countries to develop, probably even more than Europe and the US.

I just came from a sun-rich country which can do so much more. They can leapfrog directly into a large solar based generation base and avoid a lot of ecological problems, while at the same time making themselves a lot more independent from energy imports. So, there will be big game changers in the future. The big task for the utilities is to maintain grid stability, because without the diminishing spinning reserve and planned generation, how do we balance generation and demand? That will require much more smart technology and probably solutions we are yet to develop. And most of the generation will be connected to the distribution level, not to the transmission grid anymore as is now, so the tasks of the individual voltage level and the historical purpose of the grid as we know it will change fundamentally.

AR I would think the weather in Germany is much more stable than the weather is becoming in North America. Here, if you live on the southern part of the country, you have hurricanes. We have a hurricane season that lasts for four months. If you're on the West Coast, you have raging fires in the middle of the country. You have tornadoes, and also earthquakes on the west part. We are facing instability in weather all over the world, and that instability affects the stability of the grid. So, when you talk about stability, do you think wind and solar is going to allow us to be more stable because we connect directly to distribution as opposed to having these large transmission lines? Or is that going to be the challenge? For example, wind turbines in a hurricane have to be shut down.

WB There is a German term used in the renewable energy industry, called *Dunkelflaute*, which refers to dark weather with no wind. This occurs in parts of Europe mostly in the wintertime for a period of two to three weeks, when it is very cold, with only a slight wind from the east, very low temperatures and very high energy demand driven by heating. At the same time short days with almost no sun restrict yield from photo voltaic and we have to find solutions to keep the continent energized in these scenarios. A country like Germany cannot be sustainable on renewables alone. I think equivalent to around 3,000 plus terawatt hours of energy is imported in oil and gas and it will remain so in the future even if we develop wind and solar further. The U.K. is similar despite the fact it has a lot more opportunities with offshore wind around the island. The countries will need to continue to import energy and it is not realistic to believe that a highly industrialized country like Germany can become totally independent from import of electricity or energy based on national renewables alone.

The wind and solar generation goals will be accomplished by let's call it green molecules to avoid the discussion, whether it's hydrogen, methane or something else. Today we import huge amounts of oil from countries which, politically, are not entirely stable and have questionable political systems. We just face a crisis because of the lack of gas imports from Russia. We will substitute that in the future, I believe, with green molecules. And they will make up for the shortfalls of solar and wind, which is something that all the countries on the continents will face simultaneously so that even intelligent demand side management cannot ensure security of supply. So, it will be a combination of electrons and molecules, same as we have today, but mostly green originated.

AR Let's talk about micro grids a little bit. We hear about self-sustaining communities that can no longer depend on their micro grids or don't feel like they can because of weather problems. For instance, in Puerto Rico, there was a 50-billion-dollar plan to rebuild the T&D infrastructure of the Puerto Rican electrical system after the hurricanes they've had. And then there was another group that proposed building microgrids near the communities or in the communities with wind and solar generation. If you think about it, this is a major challenge, whether to rebuild traditional generation and transmission base, or build micro grids. Based on your experience, what is your perspective?

WB I would certainly take the greenfield opportunity and redesign the system from scratch rather than rebuild what was historically grown. Easy comparison. Look at the railways. Germany is running railways on 16.67 Hertz instead of 50 Hz. Nobody would take that decision again if they had a chance to go back to greenfield. So, I think as an engineer, you would never let an opportunity go when you can start with a blank sheet of paper taking an optimum approach rather than just copy pasting what has been destroyed by an unfortunate event. And many countries do that. I wasn't aware of the example of Puerto Rico, and thanks for mentioning it. But I do know, for instance, that the World Bank has been financing a thousand village program in Myanmar. Unfortunately, this is another example of a rather unstable system, and the project is, I think, paused since the military has taken over. But the project is actually focused on building micro grids. A lot of villages in Myanmar are traditionally run on old, inefficient and expensive diesel generators. The fuel is expensive, the maintenance is expensive if available at all, it's not reliable, and the villages cannot grow business on it.

Another country that is very ambitiously developing on that are the Philippines. They have still a lot of islands without entirely integrated power grids and they are moving away from planning central power stations to building microgrids. So, they try to electrify the rural area, same as Indonesia, as much as possible by microgrids, using private investments. They have tenders for concessions and the concessionaire has to bid for the lowest electricity tariff for the village and then provide a renewable optimized system for a village or a small factory included, so that there is an easy offset of the high fuel cost and a long-term sustainable solution, which also helps local communities to develop based on reliable and affordable fuel.

*Photo: Dreamstime*


AR I would like to switch briefly to battery technology. Just from what you've seen and what you are hearing in the industry, will we ever make that quantum leap to batteries and battery storage that become critically important when you go through those two weeks of darkness and no wind, and you have to have stored capacity somewhere?

WB I might not be the most knowledgeable person about battery technology, but I do study it a bit because I'm personally interested in driving an electric vehicle without a combustion engine. So, I think there will be developments in battery technology to turn traditional combustion engine into electric mobility eventually. I think that is also very likely to happen on a global scale over the next 20 years. But that's of course battery technology of a different kind, light-weight, high-power density and long-life with high number of charging and de-charging cycles.

There are many different technologies for the grid, like flow batteries where you have huge tanks which might be from a certain magnitude of storage more suitable than just the lithium-ion battery technology we know from the laptop or the electric vehicle today. So, the battery world for grid level storage is a lot bigger than just the lithium-ion technology. And there might be more than I know. I also recently came across a very interesting development looking into flywheels, apparently very efficient. There's another US start-up which is lifting big concrete blocks and stacks them above each other. In Switzerland, there is also a pilot project that is being invested in.

So, you can see there is a growing number of ideas grouping around the challenge of storing energy and how to make it efficient and usable again, like stacking concrete blocks. You can basically do that half a year later and they will not lose any of the potential energy because of the stored height. So, there will be a competition of numerous solutions and I think all of them will have their KPIs where they are really suitable and where they are less efficient. Second life of electric vehicle batteries is in Germany already in pilot projects in companies like BMW and Mercedes-Benz, where they already have grid storage projects of some 20 to 30 megawatt hours applying second life batteries. So, these are second hand batteries from the cars that do not

have good enough capacity for mobility anymore but are still good enough for grid storage purpose. So, I think at the end of the day we will look at a whole combination serving that market and controlling power to stabilize the grid. Preserving power will become more valuable and there will be a competition for efficiency and turnaround cost. How much do I get for kilowatt hours stored and how much do I get back when I bring it back to the grid?

AR That's excellent. I haven't heard about reusable auto batteries because that's always been one of the issues - what do you do with the batteries when the car is finished with them? My son has just purchased a fully electric vehicle, one of the very first Volkswagen ID Fours, but I still drive combustion engine.

WB Give it a try. Driving wise, it's much better. But of course, when it comes to driving coast to coast in the US, that's still an electric challenge.

AR I have to say Tesla is building charging stations all over so that we don't have to worry about it. There are actually 45,000 charging stations in the United States right now. We need a lot more, but it's amazing what's happening out there.

This has been a great discussion. Thank you so much. Before we end, I would like to go back to Reinhausen. You already gave us a hint of your view of the future there, but if you go out five or ten years into the future, where do you think Reinhausen will be then?

WB We will certainly not abandon the tap changer. It's amazing how much innovative potential there still is in this very mature and seasoned product. We have innovations in our drawers and we know how to industrialize them, innovations that potentially could make a tap changer half the size of what it is today. That's not a problem and we would know how to do it. The main obstacle really is how conservative the industry is. You can only introduce these innovations in smaller steps. We have launched this year a product to the market which has already some revolutionary items, an integrated tap changer based on vacuum technology. MR already revolutionized that market with the introduction of the on-load tap-changer principle in the first place almost hundred years ago, and now we are substituting oil with vacuum technology. We will fade out oil technology over the next couple of years, so there will be potentially no more oil technology from MR, at least not under our brand. And we are already working on what comes next after the vacuum technology, or how to get more out of vacuum technology? So, that will still be the main part of our storyline.

We also potentially look at disruptive switching technology like power electronics, not necessarily saying that power electronics must substitute vacuum bottles. There are certain cases where vacuum bottles are still superior to power electronics. But for years we have been busy building small statcoms. We do build, by the way, the rectifiers and inverters for microgrid systems and deliver them to battery manufacturers or micro grid developers. So, we will certainly see an increase of MR activities in the area of power electronics. And we will spin that big wheel of digitalization automation service around the tap changer. We have even had inquiries that we digitize transformers even without tap changer. So, in five to ten years, I would like to see the smart Maschinenfabrik Reinhausen or the digital Maschinenfabrik Reinhausen, which doesn't mean we are losing the capability to tighten bolts and nuts. We will still do the mechanical part of manufacturing, but it will be the same as today's cars.

Photo: MR

They have an engine which works very well, but they also have a very smart computer based interface. They have a head up display and this kind of features you can expect around the tap changer.

The electromechanical perfection is already provided today. So, the future difference is really in the level of integration, digitalization, transparency, maintainability and resilience as engineers are nothing but problem solvers. Innovative problem solvers.

WB I agree. And the really good thing is that as an engineer, and that is one of my main motivations to return to an industrial company like MR, is that almost every week, every month in the management, we have to decide which of the great ideas of our people we can finance to develop. We can give them the resources.

you can offer to your customers and the users of your technology. And that's where I see MR in five to ten years.

AR So, in a way, a digitalized MR.

WB Yes, we want to be known and recognized as a digital leader in our industry.

AR Maintaining that culture and then also being as innovative as you are talking about is really going to put MR as one of the leaders in our industry. And I appreciate the challenge that you've accepted because we We are in a very lucky position that around the transformer, we develop many more ideas. The company is capable to mature. So, it's not that we are waiting for someone to have a great idea. It is more which one of the great ideas we carry forward into the market and which ones we have to put on the waiting bench. And to an engineer, sometimes it is also a painful exercise to deprioritize an idea which in itself is great, but that's sometimes the luxury that we have in the company.

AR Excellent. Wilfried, thank you so much for this inspiring talk.

WB Thank you, Alan, for the opportunity.

# Hydrogen Management in Battery Rooms

by **Jeff Donato**

**Best practice standards such as IEEE documents and fire code state that you must deal with hydrogen in one of two ways: 1) Prove the hydrogen evolution of the battery (using IEEE 1635 / ASHRE 21), or 2) have continuous ventilation in the battery room. Vented Lead Acid Batteries (VLA) are always venting hydrogen through the flame arrester at the top of the battery and have increased hydrogen evolution during charge and discharge events. Vented Lead Acid Batteries (VRLA) batteries are 95-99% recombinant normally, and only periodically vent small amounts of hydrogen and oxygen under normal operating conditions. However, both types of batteries will vent more hydrogen during equalize charging or abnormal charge conditions.**

**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.

Photo: Shutterstock

To prevent fires and explosions, best practice standards such as IEEE documents and fire code state that you must deal with hydrogen in one of two ways: 1) Prove the hydrogen evolution of the battery (using IEEE 1635 / ASHRE 21) or 2) have continuous ventilation in the battery room.

Vented Lead Acid (VLA) and vented Ni-Cad (Ni-Cad) batteries are either fully vented or partially recombinant battery types (Figure 1). They are batteries with free-flowing liquid electrolyte that allows any gasses generated from the battery during charging to be directly vented into the atmosphere. Partially recombinant batteries will contain a catalyst device in place of the flame arrestor and will result in half of the hydrogen released into the atmosphere. In abnormal conditions, greater amounts of hydrogen gas will be released into the atmosphere.

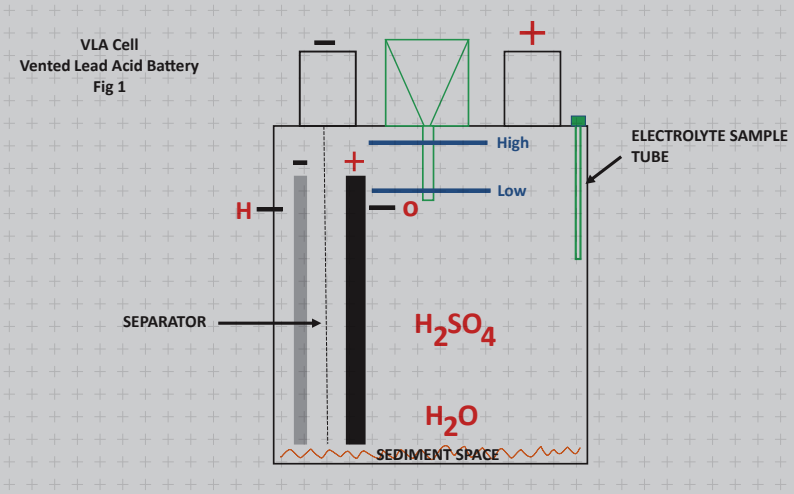



*Figure 1. VLA Cell Vented Lead Acid Battery*

VRLA battery is designed to be a non-spillable, recombinant battery. Each cell is designed with a one-way pop-up valve that is incorporated into the container (jar) to prevent gas build up (Figure 2). During normal operation, this valve remains in the closed position, trapping the hydrogen gas allowing for the recombination process to reduce water loss in the battery. The valve will remain closed if the pressure remains under the manufacturer's specification which is typically around 5 psi. However, the valve may open during recharge, equalize charge or any abnormal charge condition causing hydrogen to escape into the cabinet or room causing the potential for fire and/or explosion. This is caused by additional current that results in more recombination and heat generation that has the potential to lead to thermal runaway and greater hydrogen evolution of the battery.

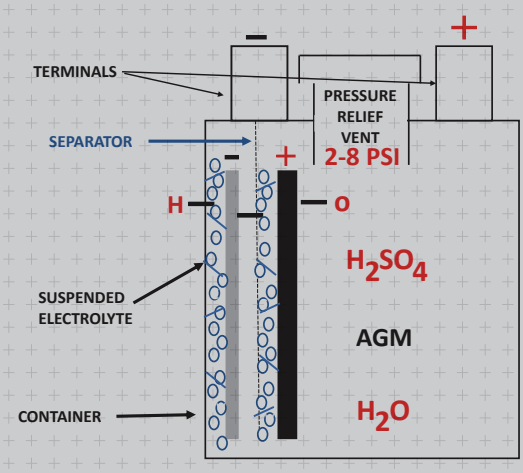



*Figure 2. VRLA Absorbed Glass Mat (AGM) Battery*

Lithium batteries are non-aqueous electrolyte batteries (Figure 3). The cells are sealed and will not vent unless they have a thermal runaway event. During thermal runaway, considerable amounts of Carbon Dioxide, Carbon Monoxide, and Hydrogen. Depending on the Lithium battery chemistry, other combustible gasses such as Hydrogen Fluoride, methane, ethane, propylene, ethylene, etc. will be produced. Lithium-Ion batteries are equipped with a Battery Management (BMS) system that controls the state of charge and monitors battery parameters but cannot control a thermal runaway event resulting from an internal short.

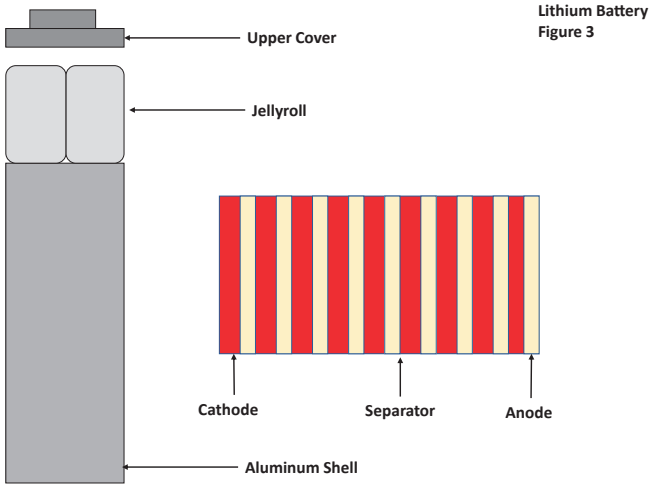



*Figure 3. Lithium Battery*

Photo: Shutterstock


New and improved sensors contain solid state, auto calibrating technology that is more advanced than legacy sensors that drifts or loses its sensitivity over time.

## Codes & Standards

Standards provide minimum requirements and/or instructions in agreement within the industry for common reference. Common standards in the battery room include those from Electrical and Electronic Engineers (IEEE), and National Fire Protection Association (NFPA).

Model codes are developed by committees with the intent to be adopted by states and local jurisdictions. Subject matter experts develop voluntary consensus standards that are saving the jurisdictions time and money by creating an industry-wide standard to follow. Once the model codes are adopted, they are enacted into law and become code.

## IEEE Standards

The IEEE 1635 ASHRE 21 standard explains the hydrogen evolution per battery type and potential heat and off-gassing types. For example, VLA battery rooms can reach 2% rise in hydrogen concentration with just half a day of equalize operation and three days normal float operation. Calculations may be found in the IEEE Std P1635™ IEEE/ASHRAE Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications.

## Fire Code

The minimum to comply with Fire Code for ESS Lead Acid Batteries is 70 kWH for Lead-acid and Ni-Cad battery types. All systems exceeding this value must comply with fire code.

*Photo: Shutterstock*

Hydrogen detection is described in the International Fire Code section 1207.6.1. Hazardous mitigation plans determine the need for hydrogen detection and evacuation to limit maximum concentration to 25% Lower Flammability Limit (LFL) or 1% of total room volume. However, continuous ventilation may be avoided by installing continuous $H_2$ monitoring and adding to your Hazardous Mitigation Plan.

According to section 1207.6.1.2.4, gas detection systems are required to contain the following features:

- Activate a mechanical exhaust ventilation system
- Ensure ventilation systems to remain on until gas detected is below 25% LEL
- Gas detection system shall have 2 hours of standby power in accordance with section 1203.2.5
- Failure of the gas detection system shall annunciate a trouble signal (NFPA 72) or audible and visible trouble signal at an approved constantly attended on-site location

***Note: The State or Local Authorities Having Jurisdiction (AHJ) may require more than what is stated in the model codes.***

Traditional catalytic bead sensors for area sensing require calibration every 3-6 months and replacement every 3-5 years. Industry experts, and Authorities Having Jurisdiction (AHJ) always been concerned about end-user maintenance practices to achieve accurate hydrogen sensing. New and improved sensors contain solid state, auto calibrating technology that is more advanced than legacy sensors that drifts or loses its sensitivity over time. These new technology sensors are made from precious metals that are not consume over time which is a game-changer in the industry. These long lasting, maintenance-free solution last over 10-years that give facility managers and AHJs renewed confidence in hydrogen sensing for battery rooms.

**References**

[1] Heinsdorf, H. P.E. (2015) *Code or standard?* Retrieved from https://www.csemag.com/articles/code-or-standard/v

[2] Wisdom Industrial Power, (2020) *What is valve regulated lead acid battery?* Retrieved from https://www.bullsbattery.com/industry-news/what-is-valve-regulated-lead-acid-battery.html

[3] EHS-DOC-146 v.1 (2018) Retrieved from https://www.concordia.ca/content/dam/concordia/services/safety/docs/EHS-DOC-146_LeadAcidBatteries.pdf

[4] N.E. Galushkin, N.N. Yazvinskaya, D.N. Galushkin (2019) Mechanism of Gases Generation during Lithium-Ion BatteriesCycling. Retrieved From: https://www.researchgate.net/publication/331793712_Mechanism_of_Gases_Generation_during_Lithium-Ion_Batteries_Cycling

[5] International Fire Code 2021

[6] Powershield (2019) Thermal Runaway and Thermal Walkaway. Retrieved from https://info.powershield.com/blog/thermal-runaway-thermal-walkaway

These long lasting, maintenance-free solution last over 10-years that give facility managers and AHJs renewed confidence in hydrogen sensing for battery rooms.

# Sabine Bowers

**Power Systems Global Renewable Energy Leader** for Cargill Bioindustrial

Interview with **Sabine Bowers**

Photo: Cargill


Cargill®
I wanted to get up every day and do something that would actually make a change in the world. I realized that the way forward for me was to get into the power industry, and specifically to work with ester-based transformer fluids.

**Women in Power Systems is an initiative that we at APC Media started last year, building a network and a community that advocates for women in all power systems roles, facilitates their connections and celebrates their successes. In this interview, we present one of these women, who found that getting into the power industry was a way for her to do something that will actually make a change in the world.**

**Dorotea Filipan:** I am Dorotea Filipan, Project Manager of Women in Power System. In this interview, I have the pleasure to speak with Sabine Bowers who is Power Systems Global Renewable Energy Leader for Cargill Bioindustrial. Sabine, thank you for joining me.

**Sabine Bowers:** Thank you very much, Dorotea.

DF Sabine, you studied Sciences and Management at the University of Manchester. Was this always a field of interest for you? And what was it that drew you to this area in particular, or who inspired you to perhaps take this direction?

SB I wanted to do a study in a field that would allow me to work internationally, and that specific degree (Sciences & Management) gave me the tools for that. My husband had also suggested for me to study in Manchester, as the city has an important industrial history. It was actually the cradle of the Industrial Revolution, so it seemed a really good place to study this topic.

DF It's wonderful to have such inspiring and supporting people so close to you in your life.

SB Yes, my husband was very supportive throughout my career including when I had to travel a lot. I have to say I am very fortunate with him in that respect.

DF Right now, you are the Power Systems Global Renewable Energy Leader for Cargill Bioindustrial, however, you didn't start out in bio industrial products. In fact, you didn't start out in the power industry at all. I believe you started out in the automotive industry and then worked for a bit in the computer industry. Could you describe your career journey from graduation at Manchester to where you are now, and how it happened? How did you get to where you are today?

*Working with natural ester fluids for transformers – a sustainable, high performing and green technology – gave me a lot of satisfaction, and still does to this day.*

SB After graduation, my first target was that I wanted to work for a large multinational company. I felt that it would be a good experience to get the feeling of the corporate world. I also wanted to understand the automotive industry and at the time it seemed to tick that box for me. I found the industry very interesting, and very challenging, but also quite old-fashioned in a sense. Unfortunately, it wasn't ticking all the boxes for me and I eventually ended up moving to the UK with my husband, which is when I began my career in the computer industry.

At the time it was the millennium, and so much was evolving in this industry. It was interesting and it was certainly stimulating, but it still wasn't hitting all the boxes for me. So, I took a break with my family. We took some time out and moved to France, giving me a chance to evaluate what I wanted from my career, and my life.

This break gave me the time I needed to look at what I really wanted to do, and I decided that I wanted to do something that is truly motivating for me. I wanted to get up every day and do something that would actually make a change in the world and in the way it was operating. I realized that the way forward for me was to get into the power industry, and specifically to work with ester-based transformer fluids, which are a big part of the green technology in the power industry.

And just like that, that was it. It was a global opportunity. Everybody needs power, whether you go to India or to Brazil or to America or Europe, its the same for the entire globe. But the question is, how do we develop this power need? How do we develop this power infrastructure across the globe, and how can we sustain and meet the need for growth in a world that is increasingly challenged by climate change and sustainability issues as well as the growing demand on the grid?

So, working with natural ester fluids for transformers - a sustainable, high performing and green technology - especially gave me a lot of satisfaction, and still does to this day.

DF You said that you wanted to work somewhere that created something that could make the world a better place. Was that one of the main factors that drew you to Cargill?

*I felt I really needed to move to a company that took environmental issues very seriously, including sustainability, but also, a company that is focused on equal opportunities, on diversity issues, and making the workplace and the world a better place.*

SB Absolutely, 100%. After my experience with other multinational companies, I felt I really needed to move to a company that took environmental issues very seriously, including sustainability, but also a company that is focused on equal opportunities, on diversity issues, and making the workplace and the world a better place to be in. It is very important for me to work for a company that takes social and environmental issues seriously.

DF I think anyone who has experienced office and company life can understand that need. You can love what you do to no end but if you don't feel properly supported, valued, and taken care of as an employee, it can eat away at your happiness very quickly.

*My greatest achievement so far is making a change in the renewable industry and creating more infrastructure safety in the power industry. I'm fortunate to be able to work with a great team that is equally motivated to drive and promote this further across the globe.*

SB I feel that Cargill is making a positive difference in the world and I'm helping the company to achieve those goals. This, in turn, is very rewarding.

DF Absolutely, working for a company that stands for the same values as you do is such wind under one's wings. Now Sabine, you have had a very rich career of over 30 years. Looking back, what would you say is your greatest achievement? I'm sure there are many, however, can you share with me what achievements you are most proud of?

SB My greatest achievement so far, from a professional point of view is really to make a change in the renewable industry, and to introduce natural ester in renewable technology. This sector was primarily working with mineral oil filled or dry-type transformers, and I succeeded in introducing a more sustainable and green fluid to this market. Furthermore, switching to a natural ester - like FR3® fluid - is not just valuable from a sustainability perspective, but it's also important from a safety perspective.

Throughout my career, I was working a lot in India, and there I recognized that infrastructure safety is a massive aspect of the power industry, and by introducing this

green transformer fluid, we can also make the transformers much safer for the entire community and the environment. The same goes for all the new transformers needed in the renewable energy industry. So yes, to answer your question my greatest achievement is to get this product into the renewable space and therefore I'm super happy that I've been appointed to be the global leader. I'm fortunate to be able to work with a great team that is equally motivated to drive and promote this further across the globe.


DF Sabine, you agreed to an interview for Women in Power System, so it stands to reason that women's networking within the energy industry is important to you. Are there any other women's organizations or networking groups that you are involved with?

SB Yes, I've recently joined the CIGRE networking group of women called Women in Energy (WiE) Net Zero Initiative, clearly acknowledging that we are becoming a much bigger driving force. I found out at the last CIGRE session in Paris, that women in CIGRE seem to dominate in work groups that are concerned with net zero/green topics in engineering. So, it's a perfect space for us to grow and network the different interests. And this group is made up of women from a wide range of positions within the industry: lawyers, environmental specialists, of course, engineers. I think I myself am the only more product-related person in there. It's very motivating to work with this group of women from all these different business areas but also geographic areas - from Australia to South Africa to Europe - seeing our common goals and working together on this important topic.

DF Sabine, you agreed to an interview for Women in Power System, so it stands to reason that women's networking within the energy industry is important to you. Are there any other women's organizations or networking groups that you are involved with?

DF That is wonderful, and I feel that unfortunately, we are currently lacking women in the workforce. And I feel that one of the most important things that we, as members and representatives of these organizations must do is to advocate for young women in schools and at universities to consider entering the

Photo: Cargill


It's very motivating to work with women from different business and geographic areas. seeing our common goals and working together on important topics.
I am very engaged in organizing cultural activities with a group of international women. Having friends from across the globe is stimulating and really helps me recharge my batteries.

energy industry and also to let them know that you don't have to be an engineer to do so or to make a difference in the power industry.

SB Yes, absolutely. I think that's what we're becoming more aware of, that we need to have diversity in our industry. We need people from different backgrounds and fields of expertise to join us to bring in different perspectives, and to understand the issues that people from other backgrounds see and deal with in their everyday life and that the energy industry could help resolve.

DF Now, I think we can agree that we are all living in a fast-paced, highly digital world, where we tend to burn the candle at both ends. Tell me, what helps you maintain a healthy life-work balance and what helps you just unwind, switch off, and recharge your battery?

SB I'm very lucky to live in a region where I have access to a lot of lakes and mountains. In the winter, I can do some winter sports, and in the summer, we go on bike tours and hiking.

On top of that, I am very engaged in organizing cultural activities with a group of international women. I live in in Munich where we have a large ex-pat community, and I organize trips across Munich and Europe with women from this community, we visit all kinds of cultural destinations: exhibitions, ballets, theatre, and the opera. This is good fun and very satisfying. Having friends from across the globe is stimulating and really helps me recharge my batteries.

DF There is a saying, and I couldn't agree with it more, that travel is the one thing that you spend money on, and you end up coming out richer because of it.

*My advice to young girls and young women who are considering a career in the power industry would be to try and find a company that can be good to you and encourages you to grow, and to find a field that really motivates you, that gives you a reason to be enthusiastic and passionate when you talk to your friends and your family about it.*

SB Yes, absolutely.

DF I have one last question for you, Sabine. We agreed earlier that we need more women to join the energy industry to help make it better. What piece of advice would you give young girls and young women to encourage them to start considering a career in the power industry?

SB When I was a little girl in school and realized I could no longer spend all my day just playing with friends and climbing up trees, I decided if I had to spend all my days working, I would want to do something that would give me as much joy as the playing did. So, my advice would be to try and find a company that can be good to you and encourages you to grow and to find a field that really motivates you, that gives you a reason to be enthusiastic and passionate when you talk to your friends and your family about it. I truly believe that that is a recipe for success.

DF It most certainly is. Sabine, thank you so much for joining us for the interview today. It's been a pleasure.

SB Thank you very much, Dorotea.

Photo: Cargill


Green power needs the green fluid.
As demand for clean power grows exponentially, using FR3® fluid by Cargill can help make your renewable energy application more sustainable, efficient and cost effective compared to alternative fluids.
Higher load capacity
More compact transformers with up to 20% more loading capacity.*
More sustainable
Global Warming Potential of zero and carbon neutral.
Cost savings
Save up to 50% compared to the cost of synthetic fluids.
FR3®
a Cargill brand
*Compared to mineral oil filled transformers.
© 2022 Cargill, Incorporated. All rights reserved.
FR3FLUID.COM

# Key Markets to Revert to Centralized Substation Automation Systems in the Future

by **Azhar Fayyaz**

**Azhar Fayyaz** is a Market Analyst at Power Technology Research. He is involved in projects on the power grid topics gathering data on network structure of distribution utilities, estimating the installed base of T&D equipment, and analyzing the information to predict future market trends. As a market analyst at PTR, he performs competitive analysis of different companies operating in a region and determine their market share for a specific product. He also has over two years of experience working as a senior shift engineer at Chashma Power Generation Station. Azhar comes from a technical background and has a M.Sc. in Power Engineering.

**Substation automation system (SAS) is a technological package consisting of hardware and software components that helps grid operators monitor as well as control the grid, both locally and remotely.**

Photo: Shutterstock

A substation automation system (SAS) is, essentially, a technological package consisting of hardware and software components that helps grid operators monitor as well as control the grid, both locally and remotely. These technological solutions provide remote control and monitoring functions to all kinds of substations (ranging from distribution voltage level up to extra high voltage level substations), leading to improved safety and increased reliability and efficiency of the grid.

Substation automation systems are usually deployed by sectors where the availability of energy is of critical importance and the capability to monitor and control the energy flows is imperative; for instance: transmission, distribution, generation, O&G, mining, and data centers, among others. Most of the substation automation systems are installed in the transmission, distribution, and generation sector whilst mining, O&G, and data centers generate a much less demand at the global level (Figure 1).

There are two types of SAS architectures that are discussed in this article, namely centralized and distributed architecture (Figure 2). In centralized architecture all the protection and control functions are provided by a single a device at the substation level, while in the distributed architecture these functions are configured at bay level (substation has multiple bays).

## Major Trends in the Key Markets of Substation Automation Systems

Certain key markets of substation automation systems, such as China, India, Germany, Saudi Arabia, the U.S., and Brazil, are of great interest for original equipment manufacturers (OEMs) around the globe. The annual SAS market for these key countries has a higher share of distributed SAS than centralized SAS (with the U.S. being an exception). However, it is expected that, in the upcoming five years, the situation will change as the market will tilt towards centralized SAS.

### China

In China, the demand for centralized substation automation system is expected to significantly increase year-on-year in the next few years. Initially, the utility sector was significantly inclined towards adoption of distributed SAS, but the market is currently moving towards the adoption of centralized SAS.
In the oil and gas sector of China for 132 kV substation, distributed SAS is preferred, while centralized SAS is given priority for 10 kV substation.
As far as the demand drivers for the SAS market are concerned, it is significant to note that distributed

Photo: Shutterstock

generation is the major driving factor for the SAS market in China. Additionally, big data, AI, and edge computing is also driving the Chinese SAS market. Moreover, China is observing substantial growth in the EV charging infrastructure, which is also adding to the demand for substation automation systems in the country.

## India

In India, the annual market share of distributed SAS is more than that of centralized SAS. At HV level, distributed SAS is more prevalent, while centralized SAS is seen more at MV level. The top three application verticals for distributed SAS are: transmission, distribution, and oil and gas. As per the estimates of Power Technology Research, in the upcoming years these application verticals are expected to move towards centralized SAS. It is significant to note that India is a cost sensitive market so the technologies that are deployed in the country are greatly influenced by cost.

Currently, microgrid and EV charging infrastructure are the two key reasons for growth in India's substation automation market. Moving forward, renewables along with data centers will be driving the demand for substation automation systems in the country.

## Germany

In Germany, the annual market share of distributed SAS is significantly higher than that of centralized SAS. Currently, the demand for centralized SAS is coming from the industry and it is expected that the demand will only intensify in the future. Subsequently, the market share of centralized SAS is expected to increase in the upcoming years in the country.

Power Technology Research has observed that offshore substations in Germany are heavily tilted towards distributed SAS (at present), but the situation is expected to reverse in the upcoming years. Owing to the integration of distributed energy resources with the grid in the country, the demand for SAS in the lower voltage level will ramp up in the next five years. It is also observed that the substantial growth in the EV charging infrastructure is pushing the utilities towards automation of their substations in the country. Furthermore, all the new substations in Germany are expected to be automated.

## Saudi Arabia

In Saudi Arabia, distributed SAS have a significant share in the country's annual market, followed by centralized SAS. It is not mandatory for distribution substations in the country to install SAS so most of the substations in the country have the

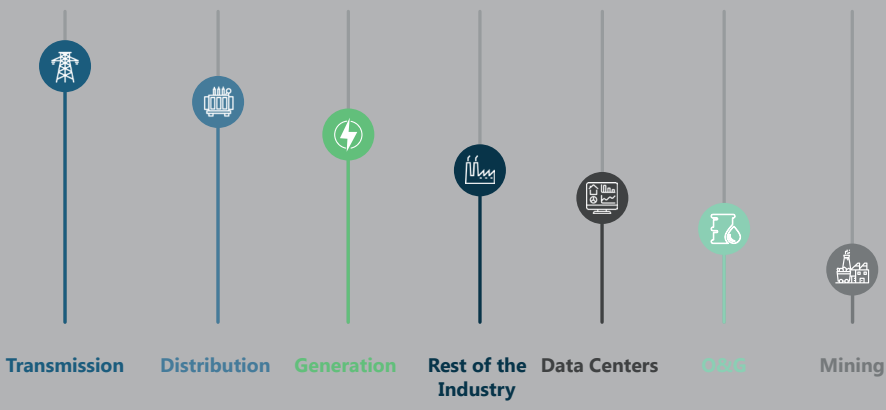



*Figure 1. Demand wise ranking of SAS applications.*
*Source: Power Technology Research*

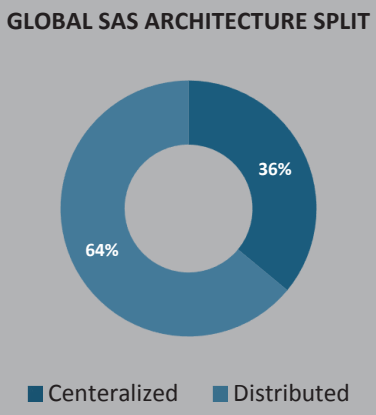



*Figure 2. Global SAS architecture split.*
*Source: Power Technology Research*

conventional RTU-based protection scheme. As per the estimates of Power Technology Research, most of the demand for centralized SAS will be coming from the distribution sector and the industry (especially oil and gas), while the transmission sector will be driving the market for distributed SAS in Saudi Arabia.

As far as the key drivers for the SAS market of Saudi Arabia in general are concerned, major infrastructure projects, like Neom City and the Red Sea City, are one of the main growth drivers for the substation automation market in the Kingdom. In addition, increased grid reliability concerns, the need for better control and command and trend for grid digitalization is also providing a push to the Saudi SAS market.

**The U.S. has a significant share of centralized SAS in the annual market compared to distributed SAS. The main demand drivers for the U.S. SAS market are the widespread deployment of electric vehicle charging infrastructure followed by the uptake of renewables in the country.**

## The U.S.

The U.S., unlike other key SAS markets, has a significant share of centralized SAS in the annual market compared to distributed SAS. In the U.S. centralized SAS are preferred and, in situations where cost is not an issue, redundant centralized SAS are also deployed. In the next few years, as per the projections of Power Technology Research, the distribution sector as well as small power plants in the country will deploy centralized substation automation systems. As far as the demand drivers for the U.S. SAS market are concerned, the widespread deployment of electric vehicle charging infrastructure followed by the uptake of renewables in the country are driving the market.

## Brazil

Nowadays, substation automation solutions are broadly requested in Brazil. The annual market share of distributed SAS in Brazil is slightly above centralized SAS. As per the projections of Power Technology Research for the next five years, the Brazilian market will lean towards centralized SAS


Photo: Shutterstock

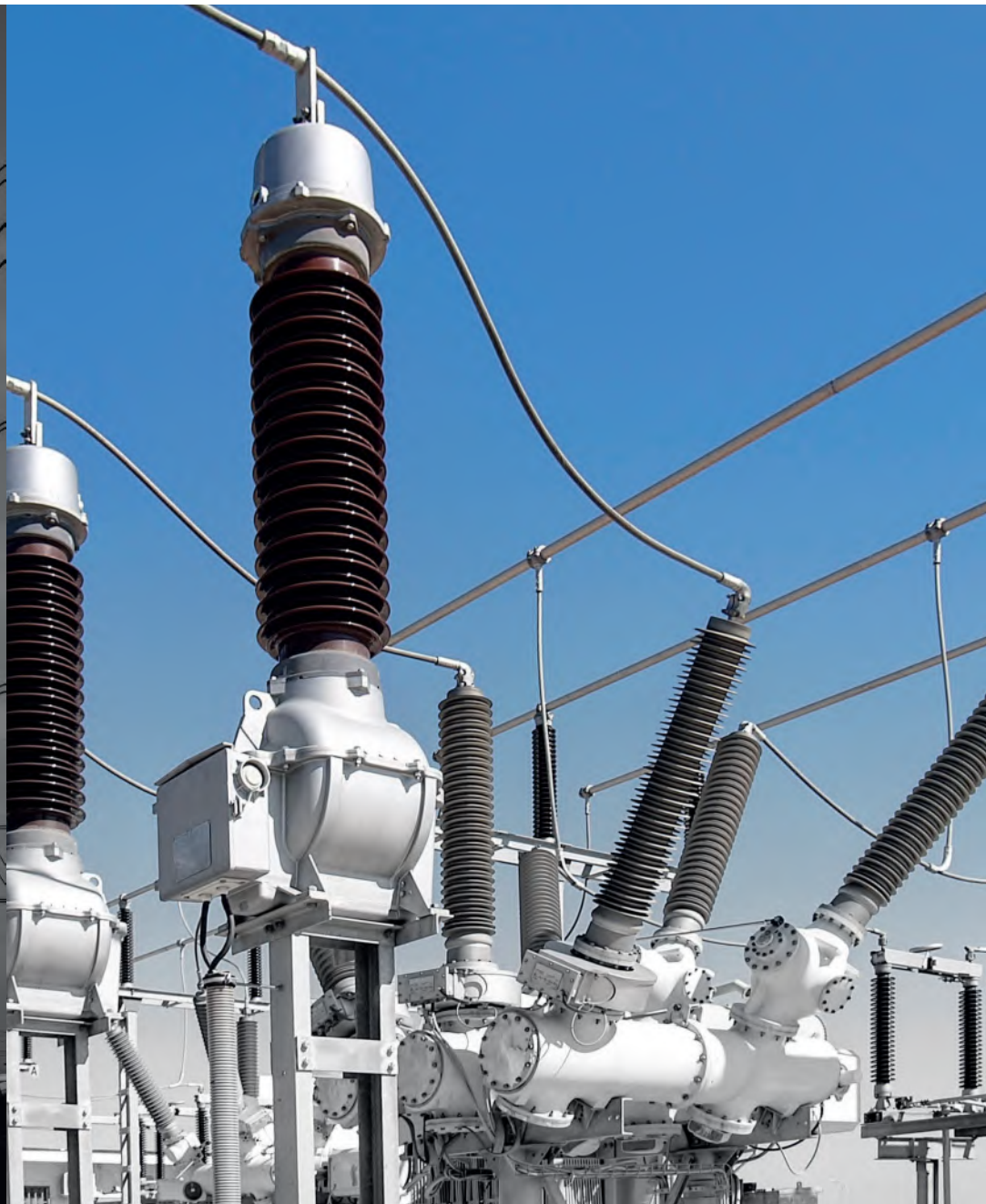
more, mainly due to the increased penetration of renewable energy with the distribution grid, followed by the increased deployment of EV charging infrastructure. Furthermore, the transmission sector is also expected to drive the demand for centralized SAS in the next 5 years.

**The digitalization of a substation will be followed by an era of virtualization, where a digital twin of a substation will exist for both control and monitoring purposes. OEMs are very keen to know if the global market will move towards the virtualization of the substations in the future or not.**

## Looking Ahead

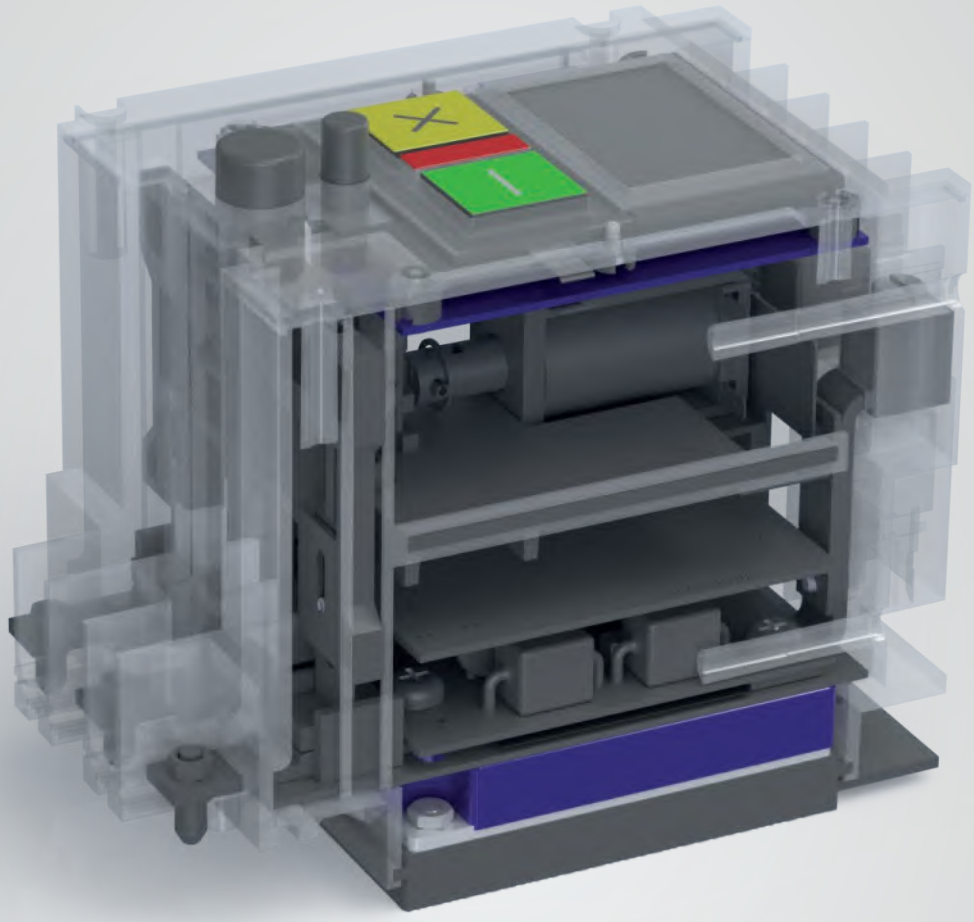
The evolutionary process of a substation is such that in the initial phase, most of the substations move towards the adoption of automation technology, followed by the digitalization of the substation. Digitalization is carried out via IEC-61850, which is an international standard that sets communication protocols for intelligent electronic devices and other equipment (protection, control, and measurement equipment) at a substation. We are currently in the era of digitalization where, along with the integration of the latest technologies with the grid, utilities are moving towards solutions that increase the overall reliability of the system. The digitalization of a substation will be followed by an era of virtualization, where a digital twin of a substation will exist for both control and monitoring purposes. OEMs are very keen to know if the global market will move towards the virtualization of the substations in the future or not.

Finally, as far as the key markets for substation automation systems are concerned, they are expected to revert to centralized substation automation systems in the coming years, which would lead to an increase in the installed base of centralized SAS. However, the U.S. is an exception as it already has a higher share of centralized SAS as compared to distributed SAS in the annual market; where cost is not a major concern, the deployment of redundant centralized SAS is also observed.



# A New Era of Solid State Circuit Protection

by **Binesh Kumar**



*With an aging power grid, and continuing shift to electrification due to the global awakening of sustainable energy, power systems are undergoing a transformation, giving rise to new technologies and industries. One of the technologies that have paved the way for new innovative solutions aiding in the power systems transformation is Solid State Technology. This term was coined in the late 1960s when the era of semiconductors began and was attributed to the flow of electricity using semiconductors as opposed to gasses in vacuum tubes, hence the term 'solid-state'. Since then, the terminology has been applied to various other industries and systems with architecture that is made up of solid, non-moving components. With material science advancements, solid-state technology is now playing a crucial role in the modern power systems transformation. After revolutionizing the semiconductor industry, the technology is now penetrating the power systems protection, in the form of Solid State Circuit Breakers (SSCBs), which we cover in this article.*

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

Photo: Binesh Kumar, Shutterstock

***One of the technologies that have paved the way for new innovative solutions aiding in the power systems transformation is Solid State Technology. This term was coined in the late 1960s when the era of semiconductors began and was attributed to the flow of electricity using semiconductors as opposed to gasses in vacuum tubes.***

## Traditional Circuit Breakers

The circuit breaker was invented by Thomas Edison in the late 1800s. Circuit breakers are analogous to the neurons of power distribution. Power flows through hundreds of breakers before it is delivered to the end customers. There are different types of circuit breakers for high-voltage, medium-voltage and low-voltage applications. Low-voltage circuit breakers such as molded case circuit breakers or miniature circuit breakers are the ones we typically see in residential panelboards. The primary use of these breakers is circuit protection in the event of overload, short circuit and ground faults. The construction of these breakers consists of a frame, contacts, lever, trip unit and an actuator mechanism.

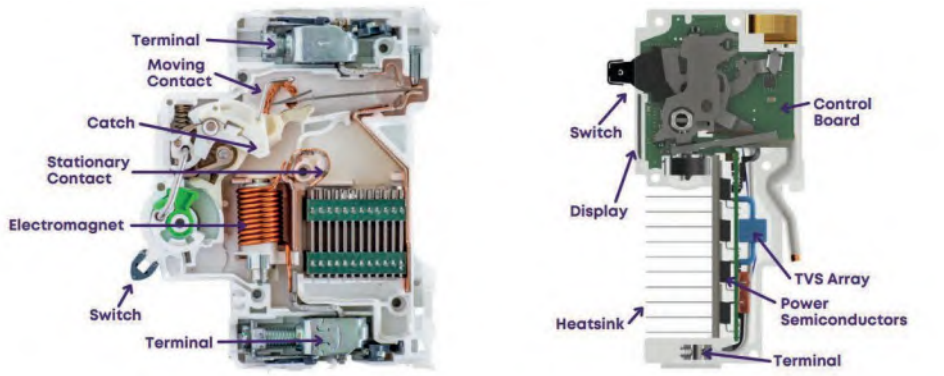



*Figure 1.*
*Anatomy of traditional circuit breaker (left) vs. solid state circuit breaker (right)*

The trip unit includes a thermal bimetallic strip that deflects in the event of an overload, thereby opening the contacts. A short circuit fault results in an electromagnetic trip opening the contacts directly.

***After revolutionizing the semiconductor industry, the technology is now penetrating the power systems protection, in the form of Solid State Circuit Breakers (SSCBs).***

A key point to note in the case of these traditional circuit breakers is that they switch the circuit causing arcs, and the breakers deploy various mechanisms to extinguish the arcs during the switching of mechanical contacts, such as using arc chambers, arc deflectors etc. This results not only in wear and tear but also could have safety implications in the event of a failure. The transients during these events could propagate through the power systems causing havoc to upstream and downstream equipment. These circuit breakers are also static in nature and cannot be configured as per the application or any changes to the infrastructure loads.

***Although there have been functionalities added to the circuit breaker over the last century, the fundamental tripping technology behind it has not changed since it was first patented by Edison.***

## Solid State Circuit Breakers

To overcome the drawbacks of traditional circuit breakers, and to pave the way for the next era in power systems circuit protection, Solid state circuit breakers (SSCBs) were invented and commercialized in recent times. SSCBs were on research papers for a long time but commercialization was not feasible until recently when the semiconductor advancements had to get to a point where the form factor and efficiency got within the desired range for commercial feasibility.

Solid state circuit breakers utilize power semiconductors to make and break the circuit. This is a fundamental shift in how circuits can be protected, since these semiconductors can be switched in the order of nanoseconds as opposed to milliseconds as in the case of traditional circuit breakers. These solid state devices are operated in the saturation region as they are acting as switches in this application.

Figure 1. shows the differences between a traditional and solid state circuit breaker. As shown, the traditional breaker has numerous moving parts that are subject to wear and tear over the lifetime, whereas the SSCB has no moving parts as part of the trip mechanism since the primary switching devices are the semiconductors.

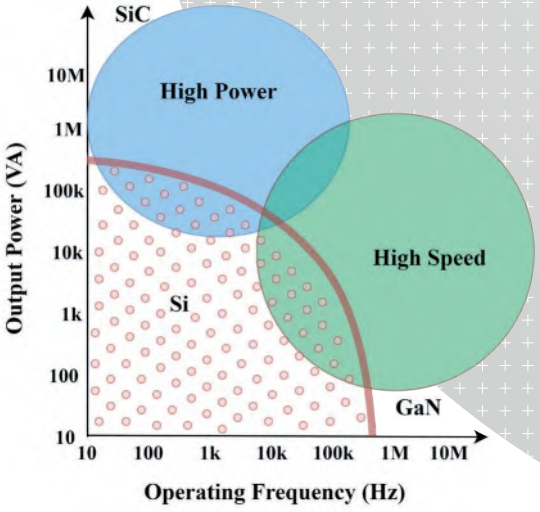



*Figure 3.*
*Comparison between Si, SiC, and GaN*

**Wide bandgap (WBG) semiconductors** are semiconductor materials that deploy a larger energy band gap than traditional semiconductor materials such as silicon. This is the energy gap existing between the upper limit of the valence bond and the lower limit of the conduction band. Due to this, they can be operated at much higher voltages, frequencies and temperatures. Figure 2 shows the difference in the construction between the semiconductor and metal. The bandgap plays a key role in the operation of a semiconductor material.

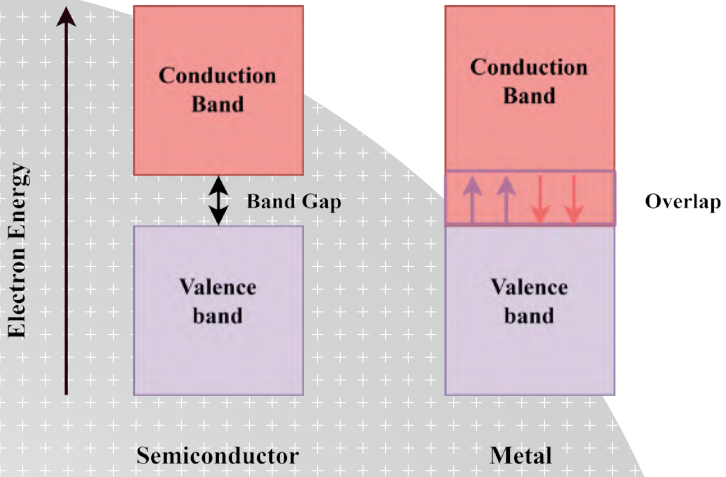



*Figure 2.*
*Band gap of semiconductors*

Some of the common WBG materials include silicon carbide (SiC) and gallium nitride (GaN). The bandgap is typically around 1.12eV for Si, while it is 3.39eV for GaN and 3.26eV for SiC [1]. Aside from GaN having a higher energy band than the SiC as mentioned above, GaN has higher electron mobility by about 30%, which is a measure of how fast electronics can move through the semiconductor material. This makes GaN more suitable for frequency RF applications that require the semiconductor to switch in the gigahertz range [2]. SiC on the other hand is more suitable for higher power applications since it has higher thermal conductivity (the ability to transfer heat). Therefore, SiC devices are obvious choices for solid state circuit breakers. Figure 3 depicts how Si, SiC and GaN correspond with each other across the various operating frequencies and output powers.

## Construction of Solid State Circuit Breakers

Solid state devices are the heart of SSCBs, as they are used to make and break the electrical circuit. Figure 4 shows the construction of a common power device used for solid state circuit breakers, the MOSFET, using the SiC substrate [3].

Some of the key parameters for the power device for the SSCB application include the ON resistance

Photo: Binesh Kumar

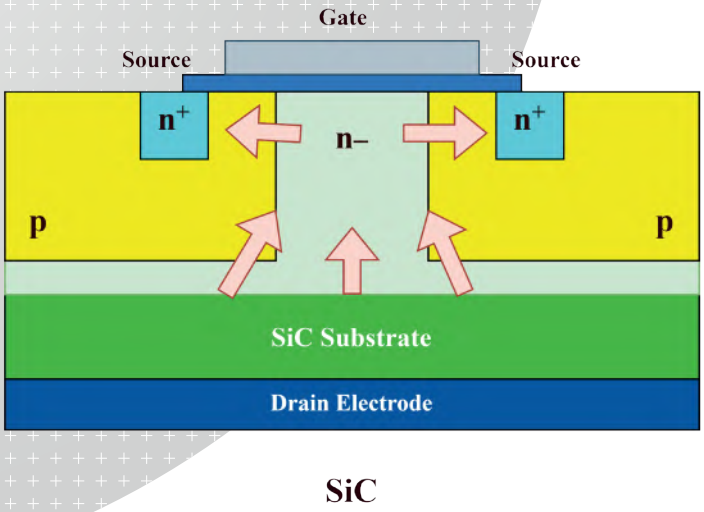



*Figure 4.*
*Construction of SiC MOSFET Device*

(RdsON) and thermal conductivity. These devices, typically made of WBG, have the ability to operate at high voltage and temperature operating conditions. While these power devices are the heart of the SSCB, the brains are composed of microprocessors, which provide the actuation intelligence to the SSCB. Due to this, the SSCB can act as smart devices with network capabilities added, enabling advanced functions such as remote control, metering, scheduling, etc. To enable full circuit protection functionalities, current, voltage and temperature monitoring mechanisms are incorporated, making the system function as a cohesive unit. The human machine interface consists of a button assembly and a display. An air gap mechanism is provided on the line side to provide galvanic isolation, which can then be locked out and tagged out in the event of maintenance and service downstream. This results in one of the key operating differences between traditional circuit breakers and solid state circuit breakers, which is the standby state. This is the state where the air gap is engaged but the semiconductor is in the off state [4].

The SSCBs can then be grouped and networked in a panel along with other SSCBs, making a smart panelboard, which can then be accessed by the outside world with the help of a user interface. This smart panel can then be used for intelligent load control and managing distributed energy resources such as solar and wind turbines, as well as for EV Charging applications.

## SSCB Features

Utilizing solid state devices for circuit breakers open up a wide range of features that could not otherwise be realized by conventional circuit breakers. Some of the key features of SSCB include:

1. **Building visibility:** SSCB can be used for adding more visibility into the building, such as power metering with high accuracy. These can be then incorporated into building management systems (BMS).
2. **Remote control:** The network capability along with the standby state of the SSCB can be used to remotely control the SSCB and in turn the loads connected to the SSCB. The ability to reset circuit breakers remotely can provide significant cost benefits by limiting downtime in the infrastructure in the case of a fault.
3. **Scheduling:** Since the SSCB panelboard can be networked to the outside world, schedule routines can be added to the SSCB, thereby adding automation to the load controls, switching them at the specified times of the day for reducing peak energy costs or other use cases.


*Figure 5.*
*100 A Frame Size SSCB*

4. **Added protection features:** In addition to the circuit breaker protection functionalities such as overload, short circuit protection, other protection features such as over/under voltage protection, over/under frequency protection can be added to the circuits, bolstering the safety mechanism to the circuits and loads.
5. **Motor controls:** Induction motors have high inrush current when they are started across the line. This can prove detrimental to not only the motors themselves but also the equipment downstream and devices on the same power line. Hence motor starters such as a soft starters or variable frequency drives (VFDs) need to be used to ensure the current inrush is limited to acceptable levels. Since SSCB has a similar construction as a soft starter, it can be used to consolidate all the motor control devices such as circuit breaker, soft starter, overload protector all into one device. This can be accomplished by ramping up the voltage as the motor starts before fully turning it on when the synchronous speed of the motor is achieved.

***The Intelligence added on top of the solid state platform makes the SSCB a Swiss army knife in circuit protection.***

## SSCB Benefits

Some of the main benefits of SSCB are outlined below:

1. **Arc flash mitigation:** Since the SSCB can be switched using the wide bandgap semiconductor material, the switching times are in the order of nanoseconds. As a result, arc flash during a short circuit fault condition is mitigated or even eliminated since the breaker does not allow energy to build up in the circuit.
2. **Configurability:** The intelligence added to the SSCB can help in ultimate configurability where the rating of the breaker can be adjusted dynamically. For example, A 100 A frame size breaker can be configured to operate anywhere between 15 A to 100 A, which is a paradigm shift from the traditional approach, where breakers have been static without the ability to change the breaker rating.
3. **No maintenance:** Since SSCB breaks and makes the circuit without moving parts, there is no wear and tear and hence there are no maintenance requirements making it highly attractive in the industry where maintenance has been a cost and time burden to operations.
4. **Smart capabilities:** With all the features discussed in the above section, the SSCB can be also termed as a smart breaker, with its multitude of capabilities making it an ideal device for the different applications.
5. **Device integration:** Modern distribution using smart grids can become very complex due to the number of devices required to perform the various functions. For example, a typical system consists of a protective relay, under/over voltage relays, meters, circuit breakers, control elements, networking devices etc. With the advent of SSCB, all these devices can be integrated into one device, which is analogous to going from a rotary phone which had just one function of making a phone call to a smartphone which has multiple functions added to the device on top of its primary function.

***A 100 A frame size breaker can be configured to operate anywhere between 15 A to 100 A, which is a paradigm shift from the traditional approach, where breakers have been static without the ability to change the breaker rating.***

## Applications

With the versatility of the SSCB, it has numerous applications in different industry sectors. Some of the key

Photo: Shutterstock

applications include but are not limited to the following:

1. **Distributed energy resource management:** With the transition from a centralized grid to a decentralized grid, SSCB will be a crucial part of the technology integration to enable this transition. This is accomplished by using the SSCB panel as the central control panel for managing the distributed energy resources and battery storage.
2. **Industrial applications:**
   a. Motor Control Center (MCC ): SSCBs with their superior control capabilities, can be used for motor controls as a unified device. This can replace the traditional MCC since it consolidates the various components of the MCC into one device, thereby saving real estate and cost in industrial application.
   b. Automatic transfer switches (ATS): The networking capabilities of SSCB open up a unique application, the ATS, where two SSCB can be operated in tandem, thereby enabling a seamless transfer of energy from primary source such as the utility grid to an alternate source such as a generator or green energy sources, and vice versa. The speed of SSCB can make it an ultra switch where there is no power glitch in this transition since the load can be switched from one source to the other in microseconds and can do a closed transition switching.
3. **EV charging:** The digital control of SSCB can prove a significant benefit in EV charging applications where the SSCB can be directly used as the electric vehicle supply equipment (EVSE). This helps solve some of the major challenges in setting up wide scale charging infrastructure, such as cost, safety, complexity and scalability [5]. This new topology of EV charging architecture, where the circuit breaker is directly used as the EVSE yields several advantages such as safety at the dispenser since the power is switched at the distribution panel as opposed to the dispenser out in the parking lot. This central control of chargers enables intelligent energy management functionalities, reducing OPEX and CAPEX for setting up wide scale charging infrastructure, in turn reducing burden to the electric grid.

## Conclusion

The benefits that solid state circuit breakers provide over traditional breakers as explored in this article make them inevitable for wide-scale integration as the world adopts the new ways by which power is generated and distributed, going from a centralized, unidirectional grid to a decentralized bidirectional smart grid. Semiconductor research continues to bring down the cost for WBG production and increase efficiency, overcoming the current drawbacks in terms of the cost and thermal limitations of the SSCB. Nevertheless, it is hard to put a price to the value of human safety, where the SSCB outshines any traditional devices by mitigating arc flash and saving human lives when fault conditions occur.

**References**

[1] Kizilyalli, Isik C., Eric P. Carlson, Daniel W. Cunningham, Joseph S. Manser, Yanzhi Ann Xu and Alan Y. Liu. "Wide Band-Gap Semiconductor Based Power Electronics for Energy Efficiency." (2018).

[2] Hernandez Botella, Juan Carlos, "On the Integration of Wide Band-gap Semiconductors in Single Phase Boost PFC Converters", Technical University of Denmark, Department of Electrical Engineering, 2015. 173 p.

[3] Langpoklakpam, Catherine, An-Chen Liu, Kuo-Hsiung Chu, Lung-Hsing Hsu, Wen-Chung Lee, Shih-Chen Chen, Chia-Wei Sun, Min-Hsiung Shih, Kung-Yen Lee, and Hao-Chung Kuo. 2022. "Review of Silicon Carbide Processing for Power MOSFET" *Crystals* 12, no. 2: 245. https://doi.org/10.3390/cryst12020245

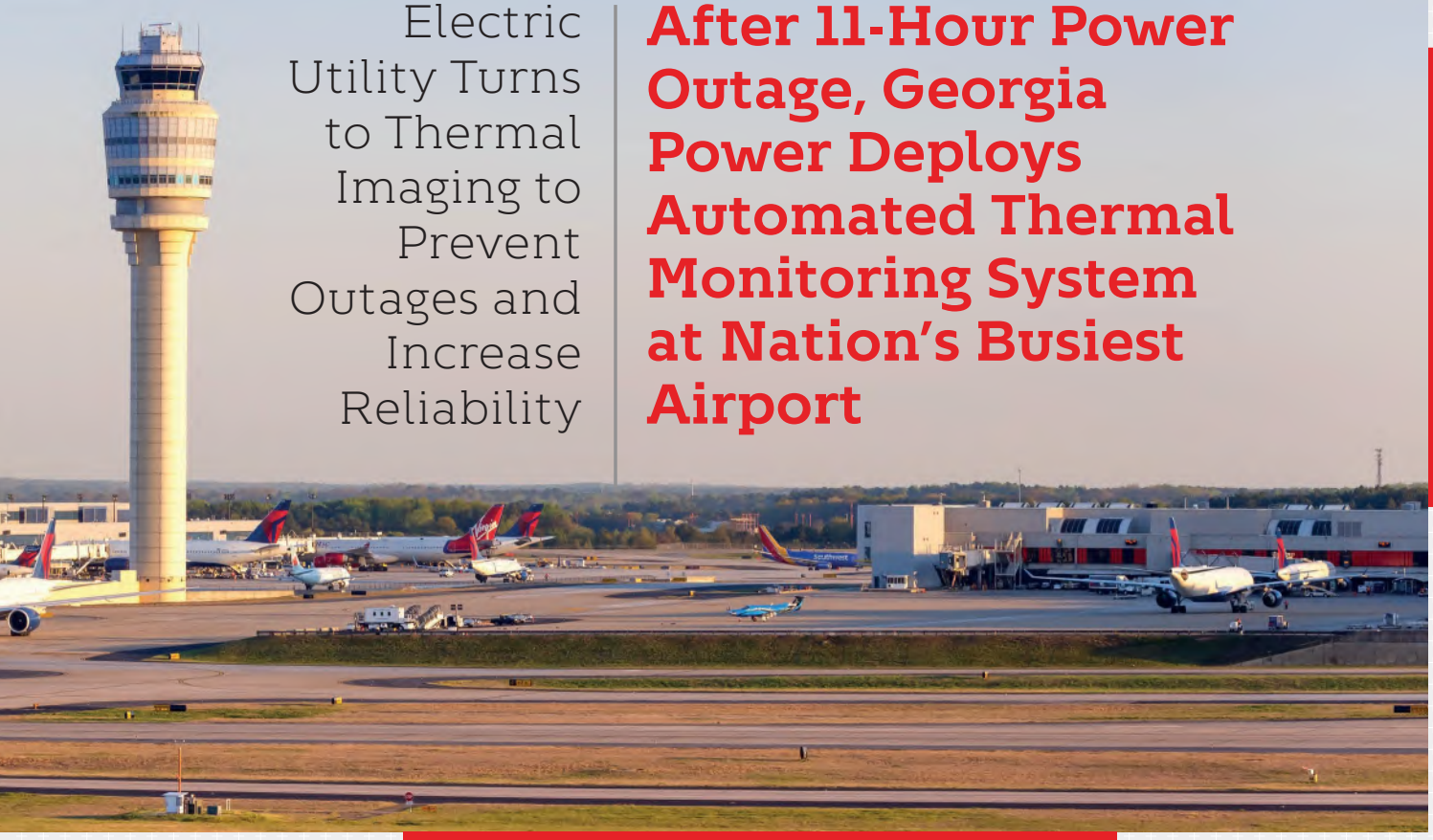
[4] B. A. Kumar and D. Leoni, "Solid-State Circuit Breakers in Distributed Energy Resources," *2019 IEEE 16th International Conference on Smart Cities: Improving Quality of Life Using ICT & IoT and AI (HONET-ICT)*, 2019, pp. 105-109, doi: 10.1109/HONET.2019.8907953.

[5] B. A. Kumar and R. Kennedy, "High-Density Electric Vehicle Charging using Wide Bandgap Semiconductors," *SoutheastCon* 2022, 2022, pp. 491-495, doi: 10.1109/SoutheastCon48659.2022.9764003.

POWER INTELLIGENCE

Electric Utility Turns to Thermal Imaging to Prevent Outages and Increase Reliability

# After 11-Hour Power Outage, Georgia Power Deploys Automated Thermal Monitoring System at Nation's Busiest Airport



## Executive Summary

On December 17, 2017, at Hartsfield-Jackson Atlanta International Airport, a component failure in the airport's extensive underground power delivery network coupled with HJAIA's backup generation not working resulted in an 11-hour outage delaying hundreds of flights.

To help prevent similar outages, Georgia Power[1] selected a continuous surveillance and early warning system from Power Intelligence, LLC[2] that uses thermal imaging cameras and advanced image processing software.

Over 100 cameras continuously measure hundreds of critical components and connections running beneath the airport's 4,700-acre footprint. Specialized software interprets the images with algorithms that provide advanced warning of degrading conditions and failing components.

### About Georgia Power

Electric utility serving over 2.6 million customers in the U.S. southeast region

Contributors:

**Dawn D. Toporek**
Georgia Power, Project Manager

**Eric S. Smith**
Georgia Power, Operations and Reliability Team Leader

## Challenges

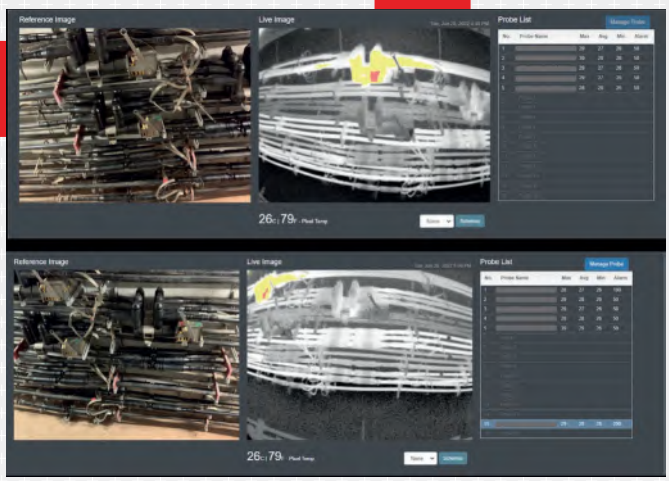
Georgia Power, a Southern Company subsidiary, serves over 2.6 million customers and is responsible for 77,094 miles of distribution lines and 12,531 miles of transmission lines powering the state of Georgia. Underground networks of redundant feeders cover the main grids of transformers powering Atlanta, Valdosta, Athens, Augusta, Gainesville, Columbus, Macon, and Savannah.

Atlanta consists of several large spot networks with multiple circuits feeding a customer with numerous transformers tied together on the secondary side to avoid power disruptions to the customer if a circuit faults.

HJAIA is served from multiple substations with multi-circuit networks feeding the domestic & international terminals and the gate concourses.

[1] *Georgia Power, https://www.georgiapower.com/company/about-us/facts-and-financials.html*
[2] *Power Intelligence, LLC, https://power-intelligence.com/about-power-intelligence/*

*Photo: Markus Mainka - stock.adobe.com; Georgia Power*


The most common failures in these underground networks occur at the connections and splices rather than the primary cable itself. Additional challenges included: A lack of a continuous equipment health monitoring system to identify component issues that could result in future failures and the airport backup generation systems failing.

Traditionally, electric utilities perform periodic maintenance of critical components typically based on scheduled intervals and expected service life. Condition-based maintenance practices deliver improved reliability because continuous monitoring provides earlier detection and opportunities for remediation.

Missing the warning signs of equipment malfunction or failure could result in considerable financial loss and damage a company's credibility and reputation.

## Objectives

Following a major outage event, most utilities conduct a post-mortem review. Learning from these outages to prevent similar future outages paves the way for implementing industry best practices.

Georgia Power sought to do the following:

- Choose a continuous monitoring solution to meet the company's needs and end goal
- Leverage technology to proactively monitor equipment to reduce the duration & frequency of outages and to prevent catastrophic failures
- Shift from interval-based maintenance to condition-based maintenance monitoring
- Evaluate additional types of monitors and sensors to determine provided benefits
- Find a company with a lasting solution that allows for expansion and enhancements

Condition-based monitoring (CBM), a strategy comprised of the real-time monitoring of equipment and key metrics, such as temperature, is used to determine when to perform maintenance.

This proactive monitoring approach involves the installation of cameras or sensors, trending the collected data, and acting when metrics exceed thresholds.

## Solution

Once Georgia Power decided to deploy a thermal monitoring solution, they did a small pilot with one vendor's solution. This solution had several limitations and would not meet their needs. Georgia Power learned about an EPRI project to evaluate thermal cameras and thermal monitoring solutions. EPRI provided their list of potential thermal monitoring solution vendors to Georgia Power.

POWER INTELLIGENCE

**Why Power Intelligence, LLC**

They were collaborative, thorough, and provided evidence-backed information for all questions.

The R&D team tested and evaluated cameras and supporting technology until they found the right solution to meet the needs of each situation.

**"Educational, knowledgeable, and backed up with documented facts, even with ideas."**

**Eric S. Smith**
Georgia Power, Operations and Reliability Team Leader

Based on what they learned in the first pilot, Georgia Power researched and interviewed these vendors. They decided that the solution provided by Power Intelligence, LLC looked the most promising and decided to pilot this solution.

The Power Intelligence team presented a solution encompassing the features that appealed to Georgia Power and worked closely with the team to deploy over 100 thermal cameras and a monitoring solution that met their needs:

- Cameras, sensors, and device configuration tools support secure remote connections
- Thermal image collection needs to work over wide area networks
- Uses a relational database to store trending temperatures
- Supports interface for SCADA polling & alarming
- Software is more developed and contains more functionality out-of-the-box

Once Georgia Power decided to deploy a thermal imaging solution, the managers compiled a list of vendors while attending an EPRI conference to provide to EPRI. EPRI began testing and evaluating the thermal imaging companies to determine if they were a fit.

Georgia Power began a pilot in conjunction with EPRI's project. The solution provided by Power Intelligence, LLC stood out above the rest and surpassed expectations through each step of the process.

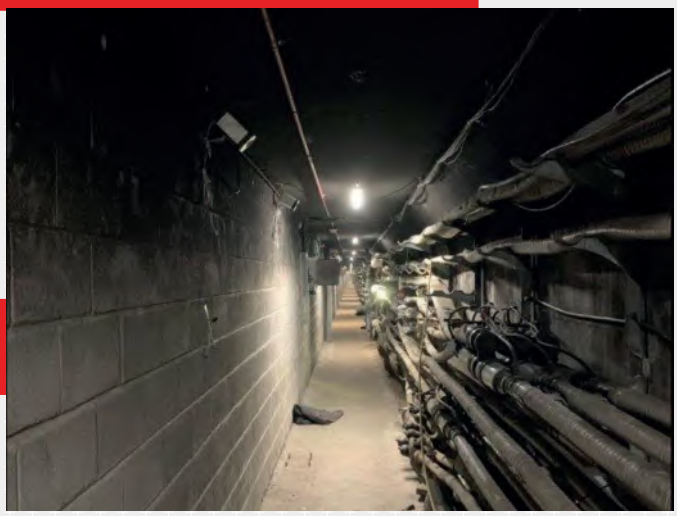
The Power Intelligence team presented a solution encompassing the features that appealed to Southern Company and worked closely with the team to deploy over 100 thermal cameras and a monitoring solution that met their needs:

- Configuration tools connect remotely
- Cameras push image files through SFTP to the server
- Uses a relational database to store trending temperatures
- Supports Modbus enterprise interface
- Mastermind software is more developed and contains more functionality out-of-the-box

Notable features:

- Live feature shot depicts changes in real-time
- Comparison tool compares a group of trending readings to another group
- Warning emails triggered with an early detection system
- Monitors 24/7 for any drastic changes to allow them to take immediate action
- Integrate with corporate security and identity management via Active Directory

Photo: Markus Mainka - stock.adobe.com; Georgia Power



## Considerations

Organizations that want to install an effective thermal monitoring system should evaluate several issues that Georgia Power considered when they developed this solution, including:

- **Goals:**
  What does the company want to achieve with the thermal monitoring solution?
  - Examples:
    - Implement condition-based maintenance monitoring
    - Prevent catastrophic equipment failures
    - Reduce/eliminate unplanned equipment downtime
    - Reduce personnel exposure to high-risk environments
- **Communication Infrastructure:**
  How does the company want to collect, store, and manage the data and thermal images?
  - Can involve:
    - Many cameras and deployment locations on a site
    - Camera and sensor remote management
    - Camera power options
- **Thermal camera selection:**
  Try different cameras in the environment
- **Solution architecture:**
  - Communication options
  - End-to-end data flows and protocols used
  - User access
  - Vendor remote access for support
  - Security requirements
- **Understand how**
  the granular details play into the bigger picture
- **Vendor risk assessment:**
  Assess vendor's security posture to determine their ability to predict, prevent, and respond to cyber and physical threats

Georgia Power recommends partnering with a company that can provide a lasting solution that allows for expansion and enhancements as industry and organizational knowledge of thermal analytics matures.

## Results and Future Plans

Power Intelligence's thermal imaging monitoring and advanced analytics solution is meeting Georgia Power's expectations. Since deployment, it has identified locations to investigate. Proactively monitoring in real-time allows Georgia Power to schedule shutdowns and make corrections.

Making repairs before a catastrophic failure occurs avoids unplanned costs and customer outages. Preventing major outages at high-profile venues maintains a company's credibility and reputation.

When the continuous thermal monitoring solution identifies a reading beyond the threshold, Georgia Power sends a technician to check with a handheld thermal camera and has found that the accuracy and reliability of the continuous thermal monitoring system's data is consistent with the field technician's handheld readings.

Georgia Power plans to evaluate deploying thermal monitoring systems at other high-profile venues.

https://www.power-intelligence.com

# Upgrade Transformer Protection with Optimal Paint Specifications

by **Maria Lamorey**

**Maria Lamorey** is a Commercial Strategy Manager at PPG. With over 20 years of industry experience, Maria plays a leading role in PPG's commitment to delivering high-performance coatings products across a variety of general industrial applications including electrical equipment of all types.


Photo: iStock

Transformer manufacturers are facing many challenges—the looming winter storm season, supply chain challenges, labor shortages and more. While many factors are beyond their control, identifying paints and coatings that offer next-level protection for important metal components is within their purview.

Considering their exposure to extreme weather conditions, outdated and substandard coatings systems can—and do—lead to impairments and disruptions in power services.

The right coating system that offers durability and resilience at every layer of protection can extend the service life of transformers and reduce the risk of coatings-related failures, a move that helps to protect their business and their brand.

It all starts with a detailed and up-to-date paint specification.

## Strong Defense Against Corrosion

When it comes to the metal components of a transformer, corrosion is public enemy number one and prevention is the top line of defense.

Metal electrical equipment parts corrode for any number of reasons. Some factors include the intersection of two metals with different corrosion thresholds, or continuous or repeated exposure to high temperatures and humidity from decades in the field, damaging pH (acid) levels, electrolytes, chemicals, and ultraviolet rays from sunlight.

## Coatings Specification: The Building Block of Better Protection

If the goal of an electrical equipment manufacturer is to build next-generation components that exceed performance mandates while protecting its brand reputation, paint specifications should be reviewed and updated regularly.

Selecting the right coating system and supplier that utilizes advanced formulations will help transformer, switchgear and other electrical equipment manufacturers outperform competitors, extend the lifecycles of their products, and reduce warranty claims.

On average, finished electrical components are composed of about 70% metal and 30% non-metal substrates. Yet most electrical equipment manufacturers view painting metal as beyond their core competency, despite the importance of high quality protective coatings on the durability and performance of their goods.

written by IEEE, UL, CSA and ASTM when painting and protecting new equipment.

Coatings manufacturers can contribute to the problem by relying on standards dictated by their customer or taking the path of least resistance by continuing with existing solutions instead of exploring more

> The right coating system that offers durability and resilience at every layer of protection can extend the service life of transformers and reduce the risk of coatings-related failures, a move that helps to protect their business and their brand.

> If the goal of an electrical equipment manufacturer is to build next-generation components that exceed performance mandates while protecting its brand reputation, paint specifications should be reviewed and updated regularly.

While most electrical equipment holds a minimum life expectancy of 20 years, many components are expected to survive 50 years or more. Harsh elements can accelerate corrosion and leave sensitive instrumentation vulnerable during storms and compromise its reliability.

Unfortunately, many manufacturers still combine old "cut-and-paste" specifications that date back 20 to 30 years with current industry-standard regulatory requirements

advanced technologies that are proven to perform better in the field.

The building block of any great coatings system starts with the right specifications. Here are some important factors to consider when specifying products.

**Coating type**—Coating manufacturers offer a variety of resin chemistries to improve resistance to corrosion and UV exposure, including epoxies, polyesters, urethanes and acrylics, as well as hybrid coatings, which incorporate a combination of resin chemistries. Each have their strengths and weaknesses.

For instance, epoxies are ideal for chemical resistance and mechanical properties, but are lacking in UV resistance and weatherability. Polyesters, urethanes and acrylics all offer exceptional weathering characteristics, but each offers a different benefit, such as great physical properties for polyesters; chip, scuff and mar resistance for urethanes; and exceptional surface appearance for acrylics.

**Product codes**—Electrical equipment producers should avoid using a specific paint manufacturer's product code. Codes can be ambiguous or difficult to find, as they often change or may be unique to a specific customer. Instead, detail the specific coatings technology the equipment demands (pretreatment, liquid, powder or electrocoat); then detail the resin chemistry of the desired coating.

**Color** – Establishing and maintaining a standard color can be challenging. It is important to detail an acceptable range of color variation and use a proven and consistent method for determining that the color of a painted parts falls within specification.

- Pantone, RAL, Munsell, and ANSI are color-cataloging systems commonly used for these purposes, although some equipment manufacturers choose to create their own in-house standards. Maintaining color standards is a whole separate topic, so it is best to work with a reputable paint manufacturer to understand the intricacies of creating a color standard and how to detail its parameters in the specification.

The building block of any great coatings system starts with the right specifications. Coating type, product codes, color, gloss, texture, product handling and storage, and performance are some important factors to consider when specifying products.

**Gloss** – Like the color spec, the gloss range specification can have a big impact on a product's finished appearance. It is important to provide a specific gloss range in a paint specification, as variations in gloss can cause the same color on a piece

of equipment to appear as different shades.

**Texture** –In the electrical industry, some orange peel (minor paint dimpling) in the finish is considered preferable, as it tends to hide flaws and wear well over time. Regardless, standards for texture types and variation should be written into the paint specification.

**Product handling and storage** – Manufacturers suggest specific rules for handling and storage in their product data sheets, including an acceptable range of temperature exposures and fixed expiration dates to ensure inventory is properly rotated.

**Performance** – Regulatory standards such as UL or IEEE should be detailed in the paint specification. These standards are written to include a range of acceptable results for products undergoing laboratory-based performance tests, which have been agreed upon by the industry for their ability to mimic real-world performance environments.

It is strongly recommended that manufacturers include performance tests that most accurately reflect a product's ability to fulfill a warranty or expected service life into the paint specification.

## The Role of Performance Testing

While many coatings systems are robust enough to pass industry-accepted performance tests, they can fail in the field because the real-world conditions can be much more demanding.

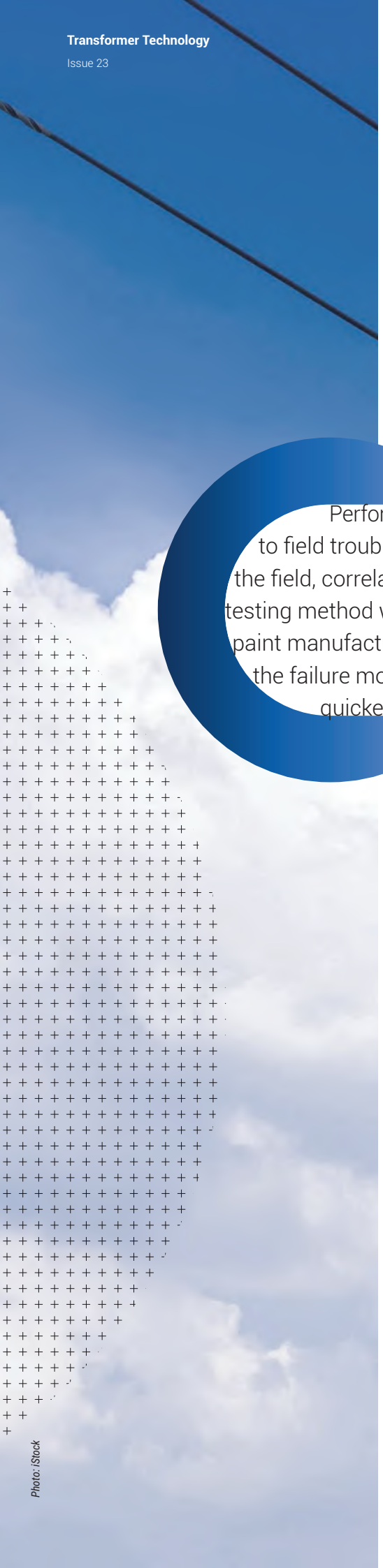


Photo: iStock

It is strongly recommended that manufacturers include the tests that most accurately reflect a product's ability to fulfill a warranty or expected service life into the paint specification. For example, does a specific impact test predict the likelihood of paint chipping once installed in the field? Or does it depict real-world color fade or coating breakdown with an accelerated weathering test?

Performance testing must correspond to field troubleshooting. If a coating fails in the field, correlating the failure to a specific testing method will enable the equipment and paint manufacturers to identify the reason for the failure more quickly, which can lead to quicker corrective action.

Performance testing also must correspond to field troubleshooting. If a coating fails in the field, correlating the failure to a specific testing method will enable the equipment and paint manufacturers to identify the reason for the failure more quickly, which can lead to quicker corrective action.

Some of the most common performance tests written into electrical equipment paint specifications include:

- Salt Spray – This is the most specified test in the electrical industry. UL1332 requires 600 hours of salt-spray exposure for electrical enclosures and switchgear. Many transformers require between 1,000 and 2,000 hours of exposure.

- Ultraviolet Accelerated Weather Testing (QUV) – In this test, coated panels are exposed to ultraviolet (UV) light of varying types, resulting in "maintain X% specific gloss level after X number of hours" rules as detailed in a specification. These tests are designed to predict how a coating will fade outdoors over time.

- Simulated Corrosive Atmospheric Breakdown (SCAB) – In this test protocol, painted panels are scribed, then cycled through exposure conditions produced in the following environments: an oven, a freezer, immersion in an NaCl solution, room temperature, high humidity. The IEEE test for SCAB required 15 total cycles with prescribed times in each area. This testing is designed to predict how well a coating will maintain its integrity when subjected to a succession of regular and extreme performance environments.

- Humidity Testing – During this test, painted panels are typically placed in a chamber for 1,000 hours, then examined for evidence of blistering or softening. This testing is designed to predict how well a coating resists water.

- Impact Resistance – For this test, panels are exposed to an array of impact hazards, measured according to pounds. Transformers are typically tested at 80 pounds of impact. This testing is designed to predict how well a coating will resist force from an object, such as a tool or machine. It also may predict a coating's resistance to chipping when a bolt or other fastener is tightened onto its surface.

- Cross Hatch Adhesion – In this test, a tool is used to cut a lattice pattern into a metal substrate. A quick pass/fail rating is assessed to the full coating system to gauge its ability to adhere to a substrate.

- Gravelometer – Road gravel is air-blasted into coated panels, which are then placed into a salt-spray chamber to assess the corrosion resistance of the exposed parts. This test is designed to predict a coating's ability to withstand road gravel and chip resistance.

Other tests that are occasionally used and built into specifications for electrical equipment include:

- Pencil hardness – During this test, a pencil is pressed through the surface of a coating to measure its adhesive strength.
- Adhesion testing – This test method involves applying tape across a painted surface in a cross-cut method, then removing it to determine how effectively the paint sticks to the surface.

There are also many types of chemical tests, including an insulating fluids test to determine a coating system's ability to resist exposure to certain types of chemicals.

> The different coating technologies include liquid, powder, electrocoat or combination. Selecting the right protective coating helps products look better and last longer, improves application efficiencies and can lower operating costs.

## Consider the Optimal Coating Technology: Liquid, Powder, Electrocoat or Combination

Selecting the right protective coating helps products look better and last longer, improves application efficiencies and can lower operating costs. But manufacturers need to consider important factors to determine the best-fit solution for the application:

A complete review of mechanical and chemical pretreatment options, the foundation of every coating system, followed by the pros and cons of electrocoat, powder and liquid solutions. By working closely with the paint supplier, manufacturers can get a clearer understanding of which coating is best, based on performance needs, application ease, environmental considerations and cost.

Liquid coatings use solvents or water and are applied to pretreated metal with electrostatic spray, dipping and other conventional methods before being air-dried or force-cured. When used as part of an integrated primer, pretreatment and topcoat system, liquid coatings offer exceptional resistance to corrosion and chemicals, excellent sag resistance and strong adhesion. Newer product offerings in waterborne liquid technologies offer a more sustainable option as part of an integrated coating layer.

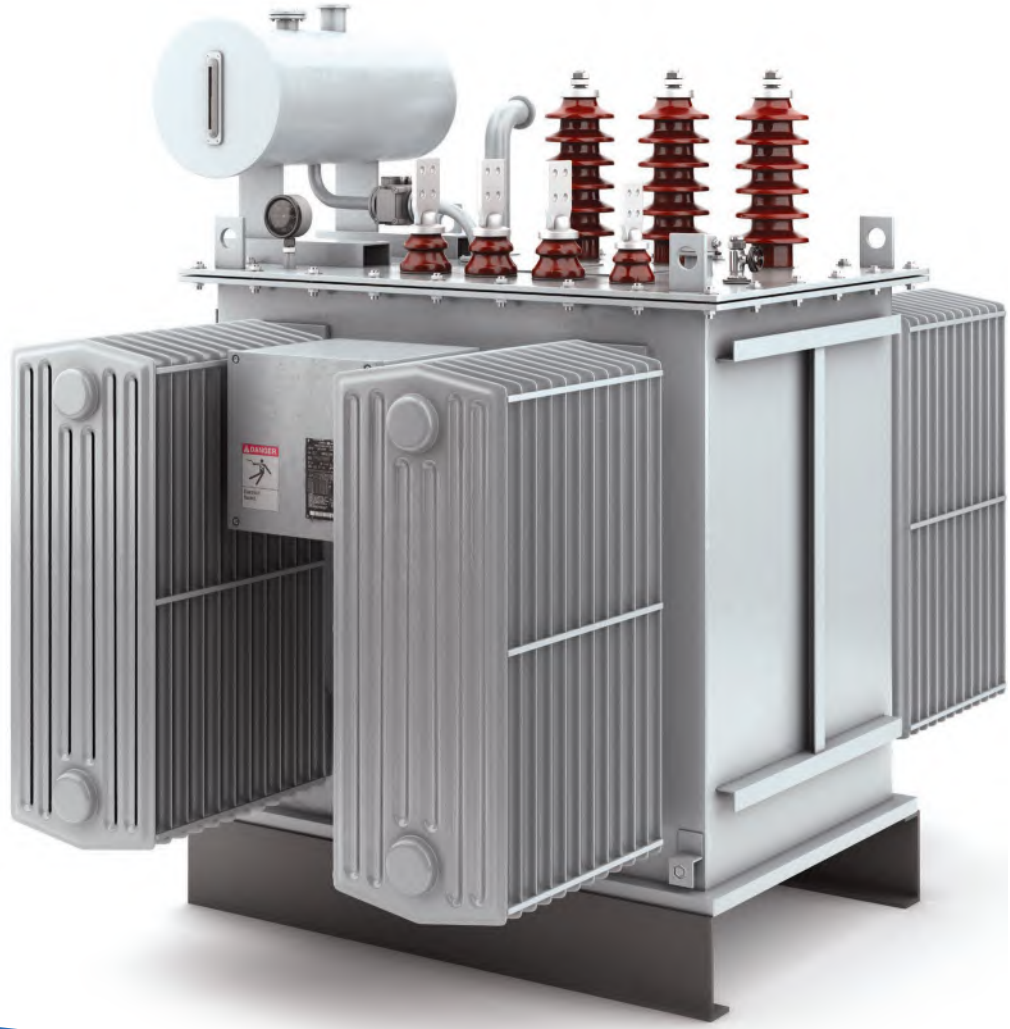
Manufacturers are also increasingly turning to powder coatings for its performance, aesthetic and sustainability advantages. In fact, powder coating is the fastest growing technology due to its performance, aesthetic and sustainability advantages.

Powder coatings are formulated for applications that require the ultimate combination of corrosion resistance, weathering performance and operational attributes. These coatings are typically formulated with specific resins combined to provide excellent corrosion and chemical resistance, as well as all-around application versatility.

Since powder coatings are made without solvents, they generate virtually no volatile organic compound (VOC) emissions, which can help to achieve environmental compliance and reduce material usage, energy consumption and maintenance costs thanks to a first-pass transfer rate of up to 85%.

Newer coatings systems offer an additional layer of protection by combining a liquid primer with a powder topcoat.

Layering is the key to more robust corrosion protection for all the coil coated metal parts on a transformer. Optimal coverage for manufacturers in this space include a two-coat system that features a primer coat for improved corrosion resistance and a top coat for durability and color.



> Equipment manufacturers should involve paint and pretreatment suppliers in the design process as early as possible, preferably with a proven coatings company that can offer both pretreatment and paint capabilities as an integrated package.

Scientists recently developed a **Coil Primer Powder Topcoat (CPPT)** system that replaces the standard DTM process with the addition of a durable liquid primer basecoat.

## Coatings Suppliers Make Valuable Partners

Equipment manufacturers should involve paint and pretreatment suppliers in the design process as early as possible, preferably with a proven coatings company that can offer both pretreatment and paint capabilities as an integrated package.

Integrated, full-service coatings suppliers typically have a deep understanding of the entire coatings process, along with a wide range of products and resin chemistries that have been tested according to standard industry criteria.

Coatings suppliers can be valuable partners by helping to identify potential vulnerabilities to corrosion and recommending protect solutions to prevent it.

Most integrated coatings suppliers have a global presence and partnerships that span a wide range of industries. This broad expertise, along with dedicated lab resources, can be invaluable to manufacturers in helping them to identify the best test methodologies to measure a product's potential service life, quickly correct coatings failures and troubleshoot general coatings-related production problems.

*Photo: iStock*

EMID

www.emid-usa.com

Your one source supplier of electrical insulation and wire materials for the motor and transformer industry

## PRODUCT LINE

- Magnet Wire (Also available in 6" spool)
- Insulation Materials (Slot Insulation, Wedges, Phase Insulation and others)
- Rigid insulation (Sheets, Rods, Dog Bone)
- Varnishes & Liquids
- Tubing and Sleeving
- Tapes& Adhesives
- Lead wire
- Telecommunication & Building Wire
- Specialty Papers & Fibers (Nomex, NMN, Copaco and others)
- Tie cords
- Pressboard
- Misc Supplies


Seneca, SC Branch
514 Concord Industrial Drive
Seneca, SC 29679
(864)-985-1106

Ft. Wayne, IN Branch
4808 Kroemer Rd. Building #2
Ft. Wayne, IN 46818
(260)-423-9529

Miami, FL Branch
8350 NW 52nd Terrace.
#301 Doral, FL 33166
(305)-392-5508


**REQUEST A QUOTE CALL US 864-985-1106**

# Dielectrics: Advances in Insulation Systems

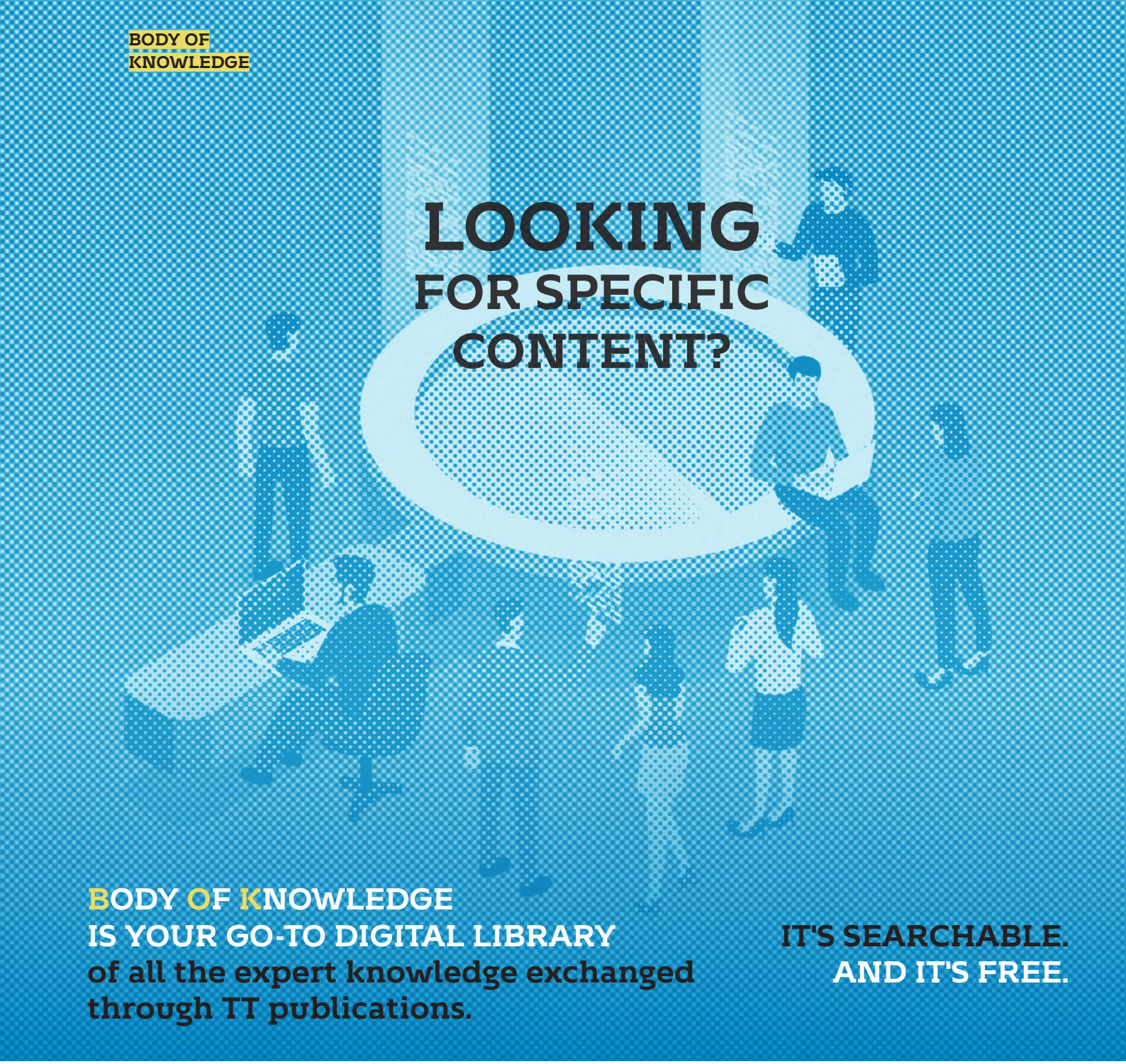
Our December 2022 Issue on **Insulation, Oils & Fluids**, while focused on fluid filled transformers, since they are such a critical part of the power system, also has an article from Technical Advisory Board member, Ben Lanz reporting on technology of insulation of cables, also an important and critical asset in power. There can be no power system without transformers and there can be no transformers without power systems around them.

The technology of oils & fluids is changing to address the issues most affecting the power industry; decentralization, decarbonization and digitalization, with mineral oils becoming more specialized to support the stresses facing new transformers and with the growing use of natural and synthetic esters. If you have something of importance or interest to share, let us know but time is of the essence as we will be finalizing the editorial content shortly. Additionally, for those companies engaged in this segment of the industry, December is a great time to get your message out there with Advertorials or Case Studies.

**Alan Ross**, *Technical Director and Managing Editor, APC Media*

BODY OF KNOWLEDGE

# LOOKING FOR SPECIFIC CONTENT?



**BODY OF KNOWLEDGE**
**IS YOUR GO-TO DIGITAL LIBRARY**
**of all the expert knowledge exchanged through TT publications.**

**IT'S SEARCHABLE.**
**AND IT'S FREE.**

TRANSFORMER TECHNOLOGY COMM

## NO LATE FEES CHARGED

**ACCESS NOW**
transformer-technology.com

Photo: Vecteezy




Photo: Andrea Piacquadio from Pexels