Transformers

SPECIAL EDITION: DIGITALIZATION 2023

MAGAZINE

TECHNICAL ARTICLES:

Sensformer - digitalized future

Digital twin of cast resin transformers

Overcoming bottlenecks in digitalization

Shunt reactor thermal failure

INTERVIEWS:

Karsten Viereck

Sebastian Kuester

COLUMNS:

Digital twin reliability

Digitalization versus sustainability

TRANSFORMERS MAGAZINE'S INDUSTRY NAVIGATOR

4 Ds innovation

Craftsmanship in the era of digitalization

Transforming transformer testing

Power of digitalization and sustainability

Digital solutions for future grid complexity

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Monitoring was yesterday - self-learning systems are the future


DIGITAL TWIN

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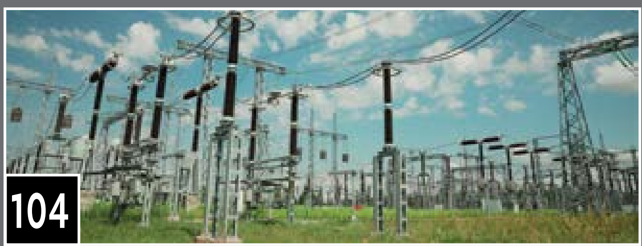
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Dear readers,

This special edition focuses on digitalization. As such, it also features articles presented at the Sustainability and Digitalization 2023 conference held in Dubrovnik, Croatia. This conference as well as the EuroDoble conference in Madrid featured panel discussions on Artificial Intelligence (AI), which is part of the digitalization umbrella. Many other events are being organised around AI and digitalization, proving that these are absolutely relevant topics that deserve our full attention.

Reflecting on these conversations, I'm reminded of my deep-rooted passion for artificial intelligence, a fascination that led me to delve into PhD research in this field fifteen years ago. As with everything else, I was initially captivated by its potential, over time I've gained some experience and become aware of its imperfections, limitations, and associated risks. Nevertheless, AI and digitalization undoubtedly offer remarkable opportunities.

I am not going to make a big analysis of the opportunities here, as they have been covered extensively in other articles, but I will just share where I saw the potential and why I decided to spend years researching it. It is data analytics around monitoring.

Data analytics is something that can be effectively managed with AI tools, which can work around the clock and detect failure mechanisms

There is a massive amount of data generated by transformer monitors, and a large part of it is never looked at by anyone, simply because we lack the skilled people even for the essential processes and we especially lack the people to analyse all that data. Data analysis is something that can be effectively managed with AI tools that are able to work 24 hours a day, 7 days a week and detect failure mechanisms. They do not replace people, but they help people. Such tools complement and augment human efforts, not replace them.

On the other hand, the potential for AI to replace human roles (jobs) is one of the greatest fears of AI sceptics. Even notable figures such as Stephen Hawking and technology pioneers such as Elon Musk have reportedly expressed concern that AI could pose an existential risk to humanity if it goes beyond human control and develops goals that are not aligned with human values. While these concerns can be subjective, security risks and misuse are objective concerns, not only in relation to AI, but to digitalization as a whole. These issues are particularly pressing in times of political instability.

Security risks and misuse are objective concerns, not only in relation to AI, but to digitalization as a whole

Moving away from these broader societal concerns and political waters, there's a practical aspect of the AI in our industry that needs to be addressed: the transparency of AI tools. On the one hand, the inventors of AI tools will tend to keep their know-how secret, while, on the other hand, users, especially users of critical equipment such as a transformer, have a legitimate interest in knowing exactly what the AI is going to decide in crucial scenarios.

I think this is the area where we as an industry should focus our efforts. We cannot influence social movements and the political situation, but as professionals we can work together to reduce the barriers that are largely dependent on us. How do we do this? I believe by fostering collaboration and increasing transparency, understanding and trust around AI systems.

By fostering collaboration and increasing transparency, understanding and trust around AI systems we can reduce barriers to AI in our industry

This edition is packed with information on many other aspects of digitalization. I hope you'll find it both enlightening and entertaining.

Yours sincerely

Mladen Banovic, Editor-in-Chief

The ambitious goals of the German government regarding electromobility and the massive expansion of heat pumps are just a few of the upcoming measures in pursuit of green electricity

Best Practices and Trends in the Power Transformer Digitalization

An Interview with Dr. Karsten Viereck

Introduction

In the world of electric energy, monumental shifts are underway. Our interviewee, Dr. Karsten Viereck, an industry expert, dissects the remarkable developments currently reshaping the sector. The ambitious goals set by the German government, such as electromobility and increased use of heat pumps, underline the transition to green electricity. These efforts are driving massive investments in grid transformation.

Yet, these investments face hurdles. The integration of digital technology without a unified strategy can lead to hidden productivity losses. Moreover, a growing workload collides with a shortage of skilled workers.

This interview explores solutions such as digitalizing power transformers and the role of artificial intelligence in reshaping energy operations, unveiling Asset Management 2.0. We'll also delve into the significance of cybersecurity and the future of the industry in a digitized world. Join us for a journey through the evolving landscape of electric energy.

Network operators and asset managers are currently facing major challenges and changes worldwide. You are very well-connected in the industry - what is your assessment of these developments?

The electricity industry is undoubtedly facing gigantic challenges, and a look at the planned investment projects of the network operators reveals massive efforts in network conversion and expansion to implement the energy transition and promote decarbonization.

The ambitious goals of the German government regarding electromobility and the massive expansion of heat pumps are just a few of the upcoming measures that show how green electricity, in particular, is replacing conventional energy sources in households, industry, commerce and transport, and is continuing to drive investment in grid transformation.

These increasing investments are encountering processes and structures that have grown over decades, giving rise to problems of which not everyone is aware. The introduction of digital technology and software without sufficient coordination can thus lead to redundancies in data models, which, in the overall operation of the energy supply, result in hidden productivity losses and large-scale projects that are difficult to manage. Furthermore, the work increase continues to meet an already very noticeable shortage of skilled workers at all stages of the process chain.

MR has been working on the digitization of power transformers for many years. What solutions are already available today to meet these challenges?

MR introduced the first online monitoring systems to the market as early as 1997. If you look at the flyers from that time, you will see the same wording as today, such as communication, database, real-time operation, expert system or intelligent equipment. In the meantime, we have arrived at the third generation of digital systems on transformers. I am intentionally not talking about monitoring systems here, as we can now talk about systems that include functional modules that can do far more than any previous systems and, above all, are now targeting a new generation of asset management and are supported by intelligent, self-learning algorithms. The best example of this is our Embedded Transformer Operating System (ETOS®), which can be adapted to the specific needs and requirements of operators and create a database that meets the new objectives.

The fundamental trends of decarbonization, decentralization and digitalization are associated with extensive regulatory changes and cost pressures

Keyword AI - what is AI already doing in the energy industry today, and where is the development going?

The fundamental trends of decarbonization, decentralization and digitalization are associated with extensive regulatory changes and cost pressures, which, together with a volatile supply situation, lead to network operations close to capacity limits. As a result of all these changes, the requirements for operating resources, asset management and network operations management are becoming more complex. The complexity has now reached a level that requires extensive assistance systems and automation functions so that system management can master the developments and implement necessary tasks and decisions.

Due to the increasing number of active network users and the associated high number of consumers and generation plants which potentially need to be regulated, a high degree of automation is necessary to master the complexity and the right technology is needed. Artificial intelligence can provide support here and will certainly be a basis for new sensor technologies and evaluation algorithms in future grid operation.

Automation requires sensors and actuators as well as secure, bidirectional data transmission. For more advanced automation, including the application of AI, the plausibility of input and output variables is elementary in order to achieve sufficient reliability of the overall system. At the moment, this is still an extremely underestimated issue. We will not get around the application of AI – its advantages are too obvious - but the uncontrolled application also bears the risk of false statements if the plausibility of the results is not questioned. At the same time, secure data transmission is necessary to be able to use AI. If self-learning algorithms, which are also attributed to AI, are taught on error-prone systems, for example, this could lead to false statements or malfunctions if not adequately observed, which, in turn, could lead to an unintentional discrediting of AI as an innovative tool.

Model-based algorithms belong to the future because they can improve the quality of conventional sensors or systems.

How can asset managers use the results of AI information - keyword Asset Management 2.0 – and what are the benefits?

Already in 2018, procedures were developed at MR that use statistical methods for the evaluation of operating equipment, including on-load tap-changers. These model-based algorithms use mass data from monitoring systems as well as data from vibroacoustic monitoring. This

enables a new quality of equipment evaluation because it allows the determination of physical properties that cannot be measured directly, for example. After all, they are at high-voltage potential. The combination of data and analytics thus leads to new usable information. This is what we call Asset Management 2.0.

In specific cases, our activities relate to the determination of the operating condition of the active part of power transformers – while the transformers are in operation. Therefore, particularly regarding limit-power transformers and reactors - which are subjected to constant stress - early detection of problems in the winding structure is made possible online without the transformer having to be disconnected from the grid. All this is achieved by evaluating simple data sets in combination with a little math.

And what does this information mean for network operators?

An increase in the service life of transformers or reactors can be achieved since

The combination of data and analytics thus leads to new usable information, which is achieved by evaluating simple data sets in combination with a little math

Digitization of the energy system, with extensive energy and data flows, requires security in the interactions within the cyber-physical system

service measures can be planned at an early stage. But this is only the beginning of the use of data and its evaluation by means of static, model-based methods. This can also be an important innovative approach in the transition to the ever-promoted curative grid operation in the context of the energy transition and for higher utilization of operating equipment.

So, there is significantly more data available than in the past - how can these volumes of data be organized?

Large amounts of data are required to develop potentially successful innovative approaches to extend asset management beyond the existing TESSA - Asset Management System. For example, the CIGRE paper in 2022, which dealt with the application of a grey-box model, required 22,500 data sets, of which one third were used only for training the model. This somewhat shows the volume of data needed for new developments.

Furthermore, we are very active in the rewriting of the IEC 61850-90-3 Technical Report describing the data models for condition monitoring and analysis. Our Automation division is the task force leader within IEC Working Group 10, which has held 90 meetings so far, thus showing the dimension of the work on this document, for which about 50% of the work has already been completed.

What about the topic of cyber security? What needs to be considered, and what are manufacturers like MR doing?

Through the extensive use of advanced technologies and applications that systematically involve sensors, centralized and decentralized controls, physical devices such as ETOS®, and various processes, the energy supply network is transforming into a cyber-physical system. The totality of these technologies will enable a flexible flow of energy and information. Modern power grids rely heavily on IT infrastructures for their control and protection functions in real-time operation. A malfunction, failure or cyber-attack on one or more smart assets can jeopardize the operation of the power grid. Therefore, data management will not be possible without cybersecurity.

Furthermore, digitization of the energy system, with extensive energy and data flows, requires security in the interactions within the cyber-physical system. Assistance systems such as ETOS® are an important component of these systems because they promote the interconnection of information technology or software components with mechanical and electronic components that communicate via a data infrastructure such as bus systems.

AI algorithms can also operate in these systems, enabling, for example, integrated real-time simulation for precise decision preparation of complex safeguarding algorithms. Such requirements for algorithms, individual components and applications have been summarized in the BDEW white paper, the basis for which is primarily provided by the IEC 62351 series of standards with the definition of the cryptographic processes to be supported. In addition, the BDEW white paper also deals with security requirements for maintenance and development processes as well as project organization, which are anchored in the IEC 2700X series of standards.

ETOS® can be adapted to the specific needs and requirements of operators and create a database that meets the new objectives.

MR had AI-based methods for sensors in use years ago, when the term "artificial intelligence" had not yet been invented

MR took on the topic of cyber security at an early stage so that ETOS® now also has all the necessary certificates. At the same time, a cybersecurity emergency response team (CERT) with a public website was set up to advise customers on all cybersecurity issues and ensure patch management.

Finally, let's talk about the future - how will digitization change the industry in the next ten years? What opportunities will arise?

MR had AI-based methods for sensors in use years ago, when the term "artificial intelligence" had not yet been invented.

Today, systems such as ETOS® allow the recording of mass data that can be stored in condensed form directly on-site at the transformer or even transferred to cloud storage via secure control-system protocols. AI systems will be used to evaluate this data in the future, but this will only be possible if plausibility problems can be solved sufficiently and reliably.

Digitization is no substitute for technical and physical know-how! Unfortunately, this is often confused by many people in the industry. On the other hand, given continually increasing volatility, a future automated electrical energy system will no longer be functional without increasing digitization.

There are great challenges to be mastered here!

Monitoring was yesterday - self-learning systems are the future

Digitalization versus sustainability

ABSTRACT

Digitalization and sustainability are driving forces in the power transformer industry, but they bring their own set of challenges. In this column, we discuss the complexities of sustainable oils and problems that arise in maintaining consistency in DGA diagnostics in this rapidly evolving field.

KEYWORDS:

DGA, digitalization, sustainability, sustainable oils, standards

DGA procedures require soft skills from sampling to diagnosis, which is not an exact science and cannot be translated into code that adequately expresses all ambiguities

Non-mineral liquids originate from vegetables such as soybeans, canola, and a few types of sunflower, each having its own logistics of pricing, availability, and social environmental impact on the community

In my previous column [1], I discussed the challenges of applying machine learning principles to Dissolved Gas Analysis (DGA).

Artificial Intelligence (AI) is a powerful technology for performing routine tasks and taking interpolated actions. Humans need to properly train sophisticated algorithms and provide continuous feedback in order to achieve a valuable expert system that can correctly diagnose transformer conditions. DGA procedures require soft skills from sampling to diagnosis and are not an exact science. Moreover, DGA is not easily translated into code that adequately expresses all ambiguities.

Power transformer sustainability is achievable today by using more environment-friendly materials, mainly in insulation. Such materials include non-mineral liquids manufactured from vegetable resources, such as ester liquids.

Modern solid insulation materials replace the classic cellulose made from vegetable sources. The former are treated synthetic materials reinforced for higher

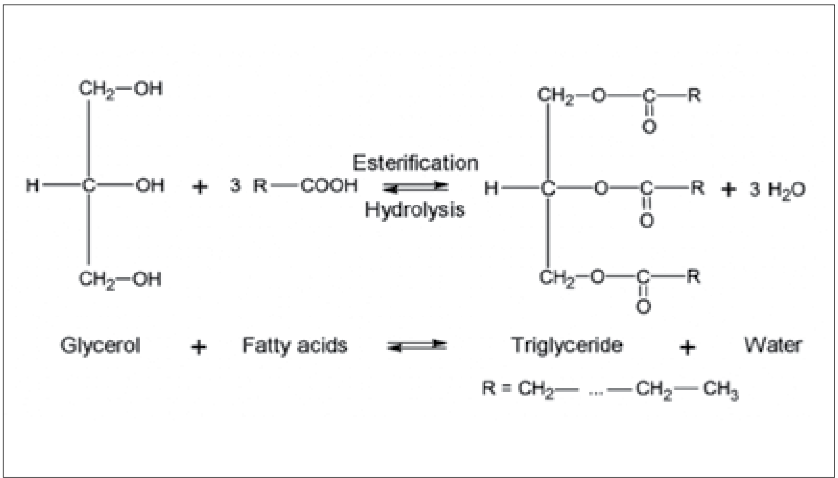

Fig 1. Ester liquid decomposition mechanism

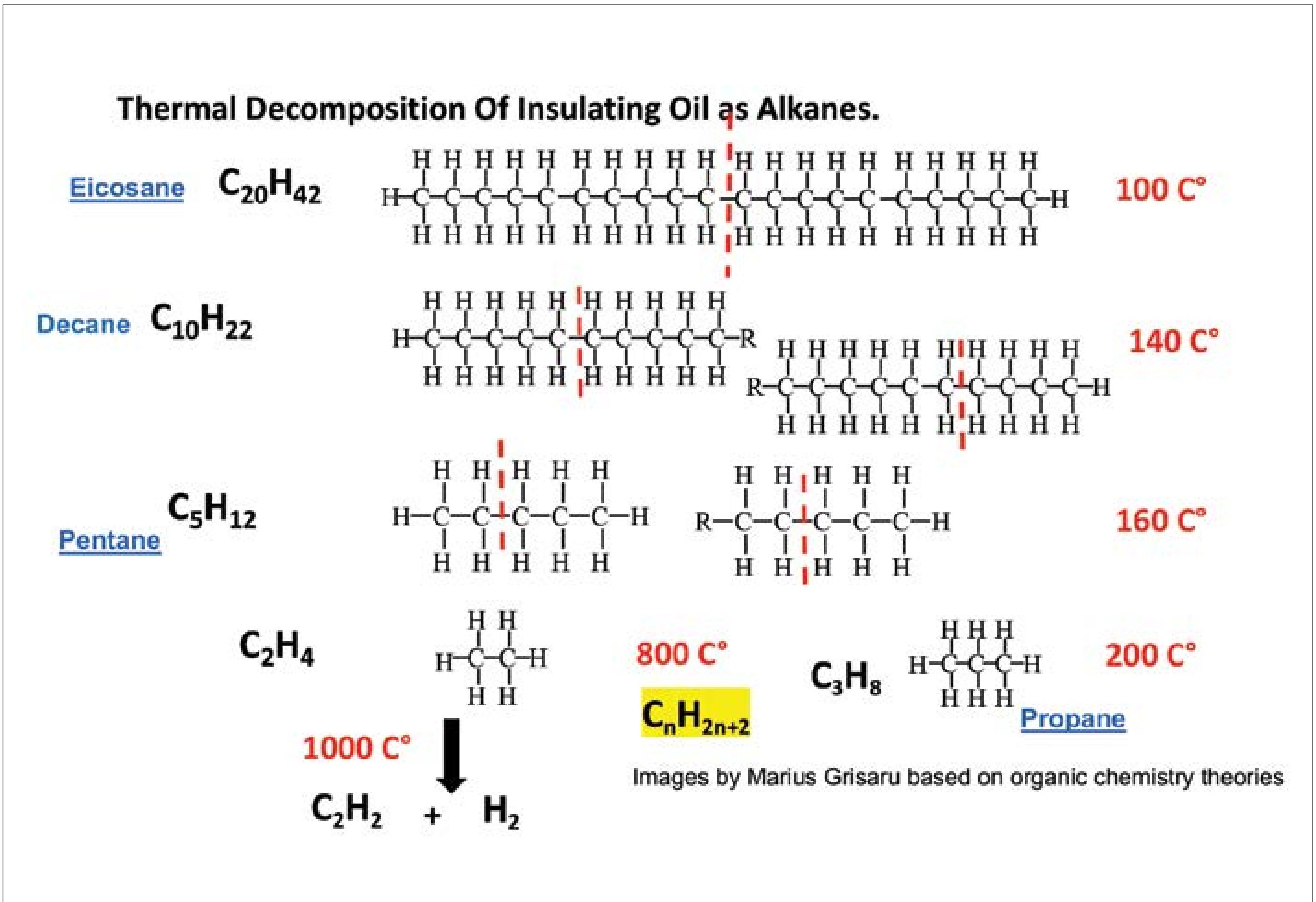

Fig 2. Mineral oil decomposition mechanism

Table 1. Different compositions of ester oils (T. V. Oommen)

Typical Fatty Acid Composition of Some Vegetable Oils				
Vegetable Oil	Saturated Fatty Acids, %	Unsaturated Fatty Acids, %		
		Mono-	**Di-**	**Tri**
Canola oil*	7.9	55.9	22.1	11.1
Corn oil	12.7	24.2	58	0.7
Cottonseed oil	25.8	17.8	51.8	0.2
Peanut oil	13.6	17.8	51.8	0.2
Olive oil	13.2	73.3	7.9	0.6
Safflower oil	8.5	12.1	74.1	0.4
Safflower oil, high oleic	6.1	75.3	14.2	-
Soybean oil	14.2	22.5	51	6.8
Sunflower oil	10.5	19.6	65.7	-
Sunflower oil, high oleic	9.2	80.8	8.4	0
*Low erucic acid variety of rapeseed oil; more recently canola oil containing over 75% monounsaturate content has been developed				

Transformer owners wishing to replace human experts who work from power transformer design to diagnosis should consider classical and well-known materials, such as kraft cellulose and mineral oil

temperatures. Also, synthetic polymers such as Nomex are more durable than all vegetable-based materials.

Non-mineral oils like natural and synthetic esters have different chemical compositions than petroleum-based mineral oils.

As shown in Figures 1 and 2, the chemistries of ester liquid and mineral oil are completely different.

Non-mineral liquids originate from vegetables such as soybeans, canola, and a few types of sunflower, as shown in Table 1, each having its own logistics of pricing, availability, and social environmental impact on the community.

Different liquid chemical structures have different properties. Researchers and manufacturers continuously improve the oil compositions of insulating liquids to meet different transformer design requirements and incorporate continuous feedback from existing installations.

Transformer owners may select non-mineral liquids from at least 10 worldwide manufacturers today, each offering at least two non-mineral alternatives.

Ester liquid products have different pour points, different gas signatures at different temperatures, different water solubilities, and, therefore, different breakdown voltage limits. Dissipation factors are also different than mineral and other liquid types.

All of these differences impose different standardizations for DGA, viz., IEEE C57.55 and the new DGA interpretation standard developed by IEC.

Software for continuous diagnoses of power transformers is designed to incorporate existent data and correlate abnormal measured values to probable fault conditions.

The need for a large, uncensored database for machine learning was discussed in the previous column. The availability of a database for non-mineral measurements is not only restricted to commercial distribution, but one still does not exist. Accordingly, machine learning and artificial intelligence cannot input, calculate, or process relevant data for power transformers filled with non-mineral oils.

Users today should realize that sustainability and power transformer digitalization cannot be achieved concurrently. Present day scholars across the world develop standards and publish numerous new conclusions on oil properties, soft-

ware diagnosis digitalization, and even power transformer design, all of which should be performed prudently and gradually after proper chemical and physical research.

Transformer owners wishing to replace human experts who work from power transformer design to diagnosis should consider classical and well-known materials, such as kraft cellulose and mineral oil.

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Author

Marius Grisaru holds an MSc in Electro-Analytical Chemistry from the Israel Institute of Technology. He has almost 30 years of intense experience in almost all transformer oil test chains, from planning, sampling and diagnosis to recommendations and treatments, mainly in Israel but also in other parts of the world. He is responsible for establishing test strategies and procedures and creating acceptance criteria for insulating liquids and materials based on current standardization and field experience. In addition, he trains and educates electrical staff on insulating matrix issues from a chemical point of view. He is an active member of relevant Working Groups of IEC, CIGRE, and a former member of ASTM. He is also the author and co-author of many papers, CIGRE brochures, and presentations at prestigious international conferences on insulation oil tests, focusing on DGA, analytical chemistry of insulating oil, and advantageous maintenance policy for oil and new transformers.

Shell Diala is a more reliable and sustainable option

The power paradox

There's a power paradox at play. The power utilities sector is at the heart of the electrification of the industry yet is reliant on its own modernization to meet growing demand - and more sustainably.

For the world to achieve net-zero, it is estimated that electricity must account for 30% of global energy consumption by 2030*. That's an increase of approximately 3.5% every year.

Investing in peak protection

To cope, grids will need some $600 billion USD of investment per annum**. Yet change won't happen overnight, placing mounting stress on existing equipment and operators. Higher loads and operating temperatures, plus increasingly remote locations and extreme conditions, mean protecting peak performance has never been more challenging. Choosing the right transformer oil is vital.

Shell's Diala range

Our Shell Diala range of high-performance transformer oils has been engi-

Diala S5 BD has high breakdown voltage to ensure excellent electrical insulating, with resistance to degradation and enhanced protection from oxidation and copper-sulphur corrosion

neered to extend oil drain intervals and keep your components in service, longer - even in harsh conditions.
Diala S5 BD has high breakdown voltage to ensure excellent electrical insulating***, with resistance to degradation and enhanced protection from oxidation and copper-sulphur corrosion****.

Sustainability built in

Shell Diala S5 BD readily biodegradable and Shell Diala S4 ZX-IG is inherently biodegradable and recyclable. Shell Diala can be reused as dielectric fluid, meeting all the requirements for recycled mineral insulating oils as defined in IEC60296.
Shell addresses CO_2 emissions for the full product life cycle. Supporting natural-based solutions and projects using methodologies that help to minimise the total amount of greenhouse gas in the atmosphere through the purchasing and retirement of carbon credits.

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**World Economic Forum. "The future of energy is systemic, open and collaborative - and runs on a smart grid." 2022.

*** Voltage above 75Kv after treatment, CAN Type II, Class A & IEC Type A

**** DIN 51353 and IEC 62535 testing

Sebastian Kuester

CEO at QUiCKFairs

Coiltech remains a family-owned business, which is important to the majority of our valued customers

Easyfairs allows me to continue my entrepreneurial activities, both through my investment in Easyfairs and my ongoing role as CEO of QUiCKFairs

Recently, there have been some significant acquisition announcements which will have a major impact on our industry. One notable merger is that of Coiltech. Could you shed a light on this?

QUiCKFairs is merging with the Easyfairs network, and I'm committed to developing Coiltech as the premier Coil Winding exhibition. I will also continue my entrepreneurial journey by taking a stake in Easyfairs while remaining the CEO of QUiCKFairs. This merger will benefit all stakeholders, especially Coiltech exhibitors and visitors, and our dedicated team.

So, this isn't a typical sale where you just walk away from the business, but you're staying fully committed to the company?

Absolutely. What sets Coiltech apart, especially from its competitors, is our deep personal commitment. Our corporate structure prioritises a long-term vision and ensures that the core values of the exhibition are maintained for all stakeholders, especially the exhibitors and visitors.

What does this merger mean for Coiltech?

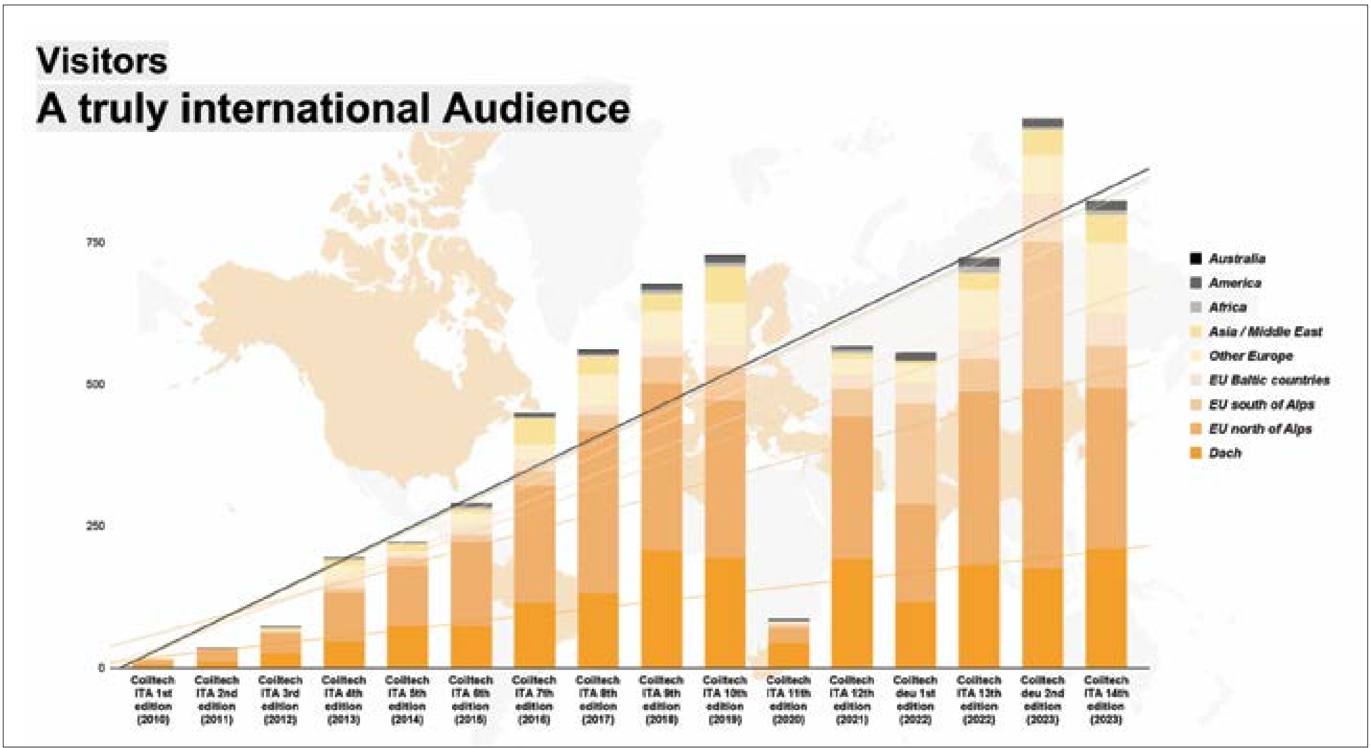
Many companies in the coil winding industry now rely solely on Coiltech. Exhibitions are, by their very nature, a "people business". It's imperative that the quality of the event remains consistent no matter who is at the helm. Partnering with Easyfairs allows me to ensure this consistency and provide stakeholders with a long-term vision. The way Easyfairs operates is very much in line with Coiltech's principles, emphasising focused thematic events, digitalisation, clear structures, and a high degree of autonomy for the execution teams.

Could you tell us a bit more about Easyfairs?

Easyfairs is a leading pan-European company based in Brussels. It consists of 20 dynamic entities that organise around 150 trade shows a year, including 18 in Germany and 3 in Italy. It's the 11th largest exhibition organiser in the world and the largest privately owned organiser. A significant 80% of its annual profits are reinvested for long-term growth. The majority ownership is held by Eric Everard and his family, with minority stakes being held by long-serving executives from its 20 subsidiaries – now also including me.

How does this transaction benefit Easyfairs?

2023 has been the most successful year for QUiCKFairs since its launch in 2010.



With record participation at Coiltech Italia and a growing presence at Coiltech Deutschland, our financial position is robust. Joining forces with Easyfairs offers us opportunities that would be harder to realise on our own.

You mentioned that Coiltech Italia achieved record numbers in 2023. Could you give us some more detailed statistics?

Certainly. In 2023, Coiltech Italia had its biggest edition ever, with 328 stands, 417 exhibitors, over 3,660 visitors, and a remarkable 38% of international visitors from outside Italy. Despite the challenging market conditions, the overall atmosphere was very positive.

Is this enough for a slogan: "Small minds confine greatness to big cities. Visionaries see beyond?"

Absolutely, this statement captures the essence of our journey. When we launched Coiltech in 2010, we faced scepticism about the feasibility of our concept in Pordenone. However, we recognised the advantages, including the proximity of Venice airport, which is as well connected as Milan. It's only a 45–50-minute drive to the venue with minimal traffic concerns. We're proud to say that our vision has paid off, with 38% of this year's visitors coming from outside Italy, proving that great things can happen beyond the big cities.

We attended the show and observed that Hall 5 bis was missing. Could you please explain this?

Certainly. The new Hall 5 bis is an upgrade of the exhibition centre, but we designated it as the new entrance area. It was completed just in time for Coiltech Italia 2023, and we wanted to assess its functionality first-hand. Our plan is to continue using it as a reception and networking area in the future.

How are the preparations for the show in Augsburg progressing?

We currently have reservations for 381 stands, which is a remarkable increase of 39% compared to the same period in mid-October 2022 for the 2023 edition.

We are particularly pleased to announce that we have more transformer-related exhibitors than ever before. This is very important because we had a chicken and egg

I would argue that Quickfairs and Easyfairs are 'genetically the same' events, both emphasising standard stands, streamlined organisation and digitalisation

problem and we are overcoming it. With over 400 exhibitors, Coiltech Deutschland is now the largest coil winding trade fair worldwide. This marks a new situation compared to the past when Coiltech was viewed by many as more of a supplement to existing events rather than the primary industry exhibition. Visitors now find certain components exclusively at Coiltech.

The purpose of exhibition is to bring visitors as well. How are you standing with this?

The larger the exhibition and the wider the range of exhibitors it offers, the more qualified visitors it attracts from both domestic and international markets. This suggests further visitor growth can be expected for the March event - both in terms of quality and quantity. Additionally, for some companies, a trade fair's position compared to competing events is a crucial decision-making factor. Currently, there is almost no way around Coiltech in this regard.

Thank you for sharing these insights. Now, let's get back to the main topic: mergers and acquisitions. These transactions often bring a lot of changes that do not necessarily make life easier. What can Coiltech's stakeholders expect from these changes?

In terms of Coiltech's core principles and operations, there will be no change. QUiCKFairs will now have a Board of Directors, with representatives from Easyfairs and myself. However, the essence of Coiltech will remain. I will continue to run the company, supported by the incredible QUiCKFairs team. Above all, my dedication to Coiltech's success remains unwavering. Being part of a global, privately owned organisation such as Easyfairs, which has been repeatedly recognised as a 'Great Place to Work,' will provide an enriching environment for our employees while strengthening a world-class business.

Just out of curiosity, is it true that you actually applied for a job at Easyfairs before you started Coiltech, only to be turned down?

Yes, that's how it was.

This is a good example of how setbacks can be part of the journey to success. It also illustrates the need to persevere in the face of obstacles. Thank you for this encouraging lesson.

Digital Twin Reliability

ABSTRACT

Digital twins, reflecting physical assets, rely on rigorous data accuracy, clear purpose, and continuous validation. This column delves into potential pitfalls, including data security and model maintenance, emphasizing the balance between model and reality.

KEYWORDS:

Digital twin, data accuracy, algorithms, reliability, modeling, cyber security

What is a digital twin?

"So, what exactly is a digital twin?"

Well, start with what you want the twin to do – model the health of the transformer, identify the need for maintenance, plan for contingency loading, prevent condition-based failures, or all of the above?

Once you've decided that, then work out what data is needed (and at what precision/accuracy and update rate), how to get it (and where from), what calculations to run (and how frequently), and what outputs to have (and how to display them). Most digital twins have some form of graphic or visualization, but they are still based on a simple process of input data – analysis – output data – visualization.

There is an old and oft-quoted line from a statistician: "All models are wrong, but some models are useful" [1], but it is seldom that the subsequent follow-up line is also quoted: "The practical question is how wrong do they have to be, not to be useful" [2]. And that usefulness is dependent on what you want the twin to do.

For example, a smartphone app that displays maps could help me get from some real address at point A, to another real address at point B. I'm not too worried about, say, how well the roads and buildings are colored in, how wide they have

Most digital twins have some form of graphic or visualization, but they are still based on a simple process of input data – analysis – output data – visualization

the map roads compared to each other and so on: I know they are wrong, but not in a way which affects me. I just want to know how to get from A to B in an efficient manner. I will only be disappointed if it doesn't actually give me a sensible route. There are cases of people following such apps in the dark, turning onto railway tracks, or ending up in a canal. I think they would be entitled to be very disappointed.

Is an AHI a digital twin?

So, is a transformer asset health index (AHI) a digital twin? I did have a free and frank exchange of views on this topic earlier this year with some folks at an industry working group. My contention would be that an AHI is a digital twin, as it represents the health of an asset and can be used to support decision-making. Admittedly, it is a very coarse twin, consisting of just one value, the index, and if you don't have a sensible, auditable, calibrated AHI, it could even be an evil twin and provide misleading information. If you want the twin to have cute graphics and pretty colors, we can add those – provide a color on a red-yellow-green spectrum which indicates the urgency of whatever intervention is needed.

You could, as we do at Doble, provide a systematic AHI based on failure mode analyses of components such as bushings, windings, oil, cooling, etc., that generates individual health indices for each one.

The twin is there to provide data to support a decision – even if that decision is a default decision to "do nothing" over and above what is normally done

> **There are many challenges with twins, from cyber security and data poisoning to twin maintenance, but the biggest challenge is that the twin may misrepresent the reality it is modelled for**

This then gives more numbers to put on the graphic, and it becomes a less coarse and more useful/detailed twin. The algorithms used to transform the input data to the output data are crucial to how well the twin represents reality. Assuming the input data has been verified and validated [3] we can compare the output data with reality and quantify the difference. For example, if a transformer loading scenario predicts a hot spot temperature of 140°C when we have continuous 1.2 p.u. load for 2 hours on a day when the ambient for the two hours is a constant 20°C , and the cooling is fully operational, we can check that against reality. In fact, we should check how well hot spot temperatures are predicted when just normal loading is applied as well – are the algorithms in the twin accurate?

The twin is there to provide data to support a decision – even if that decision is a default decision to "do nothing" over and above what is normally done. We know the twin is a model of a real object and thus will not be perfect. But we will need to know when it is wrong in a way which is important – in a way which means we may be misled into inappropriate actions. If I use a digital twin to model a GSU at a power plant to identify and prevent failures, I may not worry about small deviations of predicted hot spot temperature from reality, but if I know the hot spot is, in fact, 60°C and my twin says it was expecting 80°C , that implies there is a serious problem in the twin algorithms which need to be addressed. We know there will be some variations, but let us not worry too much about mice when there are tigers abroad.

Twin reliability metrics

How, then, do we measure the reliability of a twin? That can only be done by understanding several things:

- the aim of the twin, and what is an acceptable variation from reality
- the accuracy/precision of the input data
- the impact of the accuracy/precision on the algorithms used
- the consequent uncertainty in the outputs of the twin
- the actual variance between twin values and reality

We can consider how badly the twin varies from reality, and what that variance is doing over time, but these variations may be mice in comparison to the tigers out there, such as the one where we make a wrong decision based on twin output: leaving a unit in service to then see it fail, or taking an outage and swapping out a bushing when there is nothing wrong with it.

There are many challenges with twins, from cyber security and data poisoning [4] to twin maintenance (which is required to make sure the twin models the actual physical asset as it is, not as it was some time ago) [5], but the biggest challenge is that the twin may misrepresent the reality it is modelled for.

Acknowledgments

Thanks to Philip, Richard and Ken for their assistance with this article.

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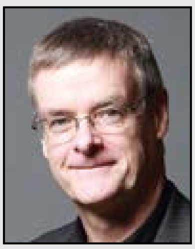


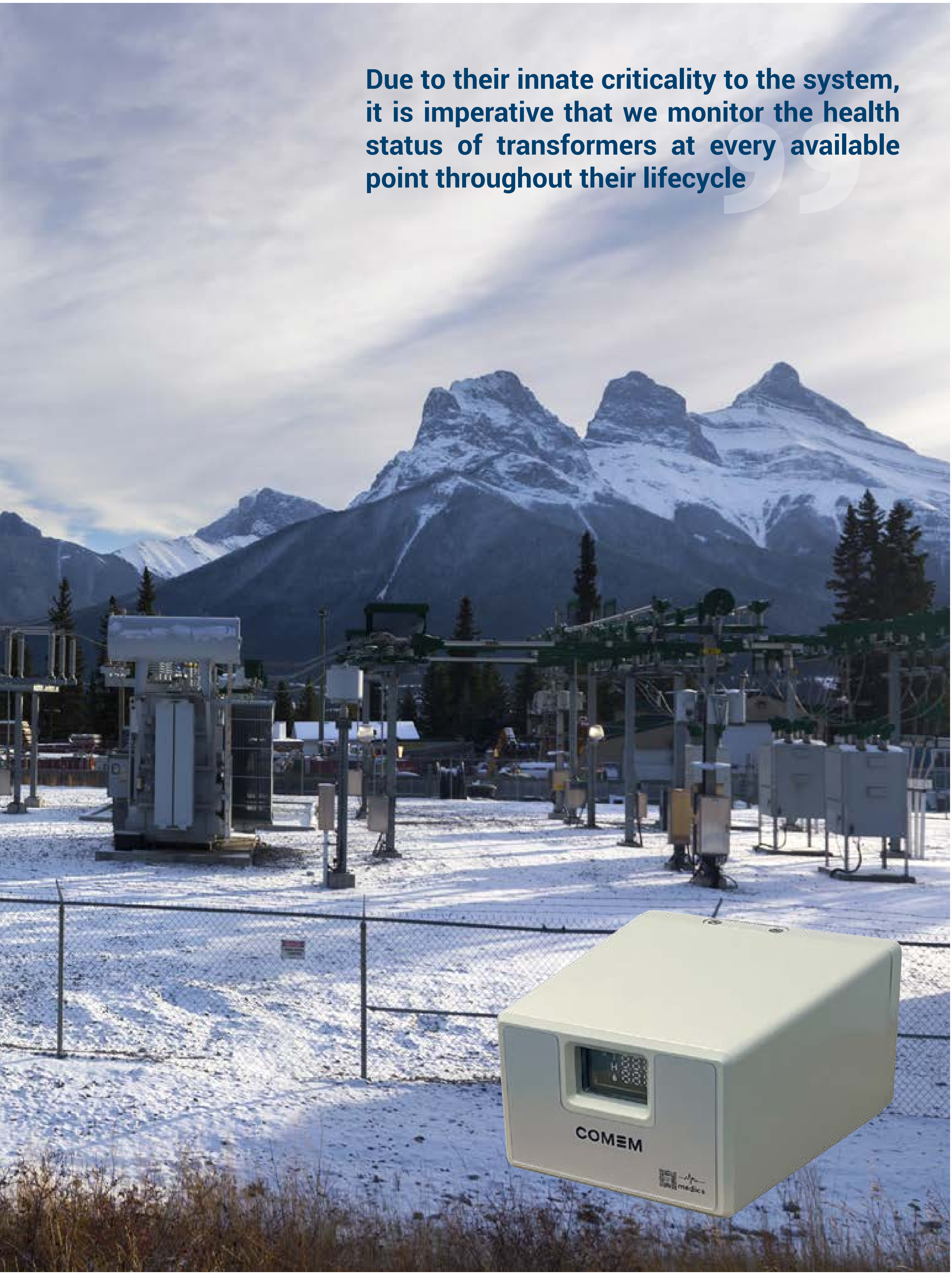
Dr. Tony McGrail is the Doble Engineering Solutions Director for Asset Management and Monitoring Technology. He has several years of experience as a utility substation technical specialist in the UK, focusing on power transformer tests and assessments, and as a T&D substation asset manager in the USA, focusing on system reliability and performance. Tony is a Fellow of the IET and a Member of IEEE, CIGRE, IAM and ASTM. He has a degree in Physics with a subsequent PhD in Applications of AI to Insulation Assessment.


Transformers
MAGAZINE

From transformer monitoring to predictive maintenance

Prolong asset life and lower your total cost of ownership!

Due to their innate criticality to the system, it is imperative that we monitor the health status of transformers at every available point throughout their lifecycle



Continuous monitoring of asset parameters allows you to collect data and use trend analysis to spot patterns and predict future events

Transformers are irreplaceable components of any power system. They are designed to last approximately 30 – 40 years and play a vital role in delivering power to the consumer. Due to their innate criticality to the system, it is imperative that we monitor the health status of these valuable and expensive assets at every available point throughout their lifecycle.

There are many challenges for transformer end users:

- Gathering relevant health data remotely to make informed decisions.
- Building a suitable transformer maintenance strategy.
- Prolonging transformer life and lowering transformer total cost of ownership.

… and many asset health parameters to keep under control:

Temperature

With the global increase in energy demand, the average loading on transformers rises and the end users strive for higher asset utilization. Higher loads mean hotter operation and the need for improved thermal management. However, overheating affects the insulation material properties and causes transformer aging.

Load

The operator can define the overload capacity of the transformer over time with a precise definition of the immediate risk, making the most of the transformer's potential without compromising its lifespan.

Moisture

Humidity accelerates the insulation material aging. The presence of moisture is an indicator of an abnormal condition, and further investigation is needed to determine the next course of action.

Gases

The oil must be stable at high temperatures and have excellent electrical insulating properties to withstand electrical and mechanical stresses and assure the safe operation of the transformer. Dissolved gases present in the transformer oil are indicators of possible faults.

Gas accumulation

Detecting abnormal gas accumulation and abnormal rate of gas accumulation in the transformer provides valuable insight into internal malfunctions, allowing the opportunity to promptly shut down the transformer and prevent possible destruction of transformers.

Pressure

Pressure in the transformer is one of the key health parameters that predict early signs of decreased performance or an upcoming failure. Overpressure in the transformer tank can lead to an explosion and a hot oil spill in the surrounding environment.

Oil level

Liquids like mineral and silicone oils insulate and cool a transformer. It's essential to monitor the oil level to ensure reliable and safe operation of the transformer.

Continuous monitoring of asset parameters allows you to collect data and use trend analysis to spot patterns and predict future events.

Just like proactive and regular healthcare for the human body, preventive maintenance programs based on regular testing and data interpreting have become fundamental for improved transformer lifespan quality and significantly increased it.

Decisions on proactive transformer healthcare should be taken upon relevant data analysis and consist of monitoring, testing, and consulting services. A digital transformation journey moves from a process-defined world to a data-driven world.

Traditional time-based maintenance scheduled on fixed set-time intervals and manual data collection is not efficient enough in an era where technology is rapidly advancing and where customers have a need for speed and seek an immediate response to questions.

Digital monitoring allows you to gather relevant data remotely and in real time and to have full control over the course of anomalous events. The availability of more detailed information enables a wider evaluation of both asset operation and maintenance strategy. Furthermore, you can avoid errors caused by manual sample collection and being caught off guard by unexpected events.

Choose the right solution for transformer digital monitoring and adopt a reliable data collection system that fully integrates with your transformer protection and control systems.

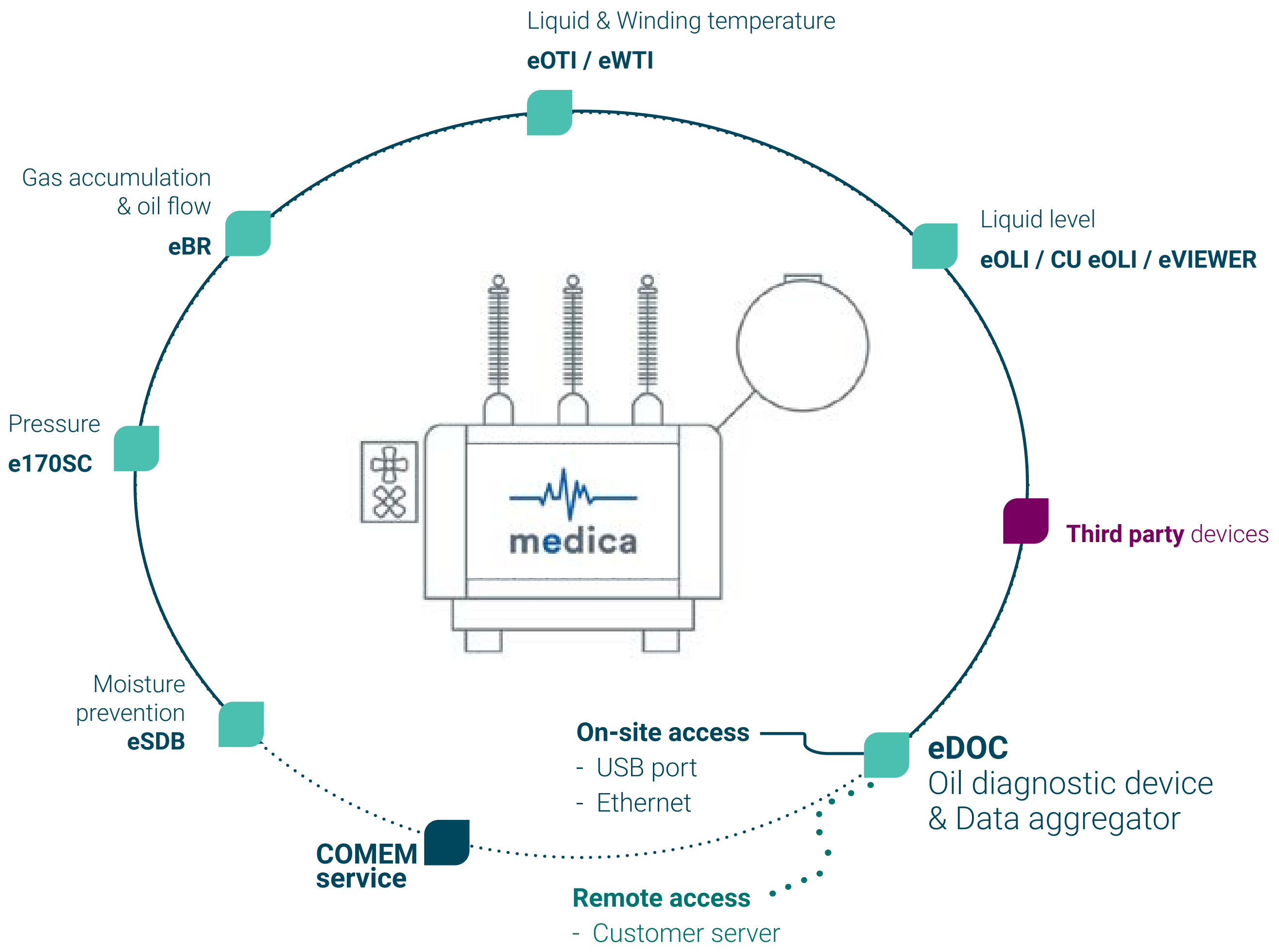
MeDICA is a modular ecosystem designed for specific customer needs, which can be adapted over time. The solution consists of hardware – safety monitoring devices, sensors, data aggregators - and services.

By integrating and interpreting data from online monitoring and offline testing, we can build a sustainable maintenance program and guarantee a longer lifespan for your transformers.

MeDICA is a modular ecosystem designed for specific customer needs, which consists of hardware – safety monitoring devices, sensors, data aggregators - and services

Dissolved gases in transformer oil

The demand for reliable and sustainable power continues to grow, and the transformers that are currently in service are subject to increased stress. Unfortunately, this increased stress accelerates the aging of the insulating systems, thus



The presence of dissolved gases and moisture is an indicator of an abnormal condition, and further investigation is needed to determine the next course of action

reducing the reliable life of these critical assets.

Insulating materials inside the transformer liberate gases while breaking down.

To make sure transformer oil is suitable for use, end users must periodically control its properties. The presence of dissolved gases and moisture is an indicator of an abnormal condition, and further investigation is needed to determine the next course of action.

Sensors are essential for transformer monitoring, enabling end users to monitor asset health parameters, plan for proper maintenance, and prevent failures. By combining the results of electrical tests with oil analysis, you can obtain a complete status of the transformer's health.

Dissolved Gas Analysis (DGA) is among the most powerful tools for detecting faults in power transformers.

By **trending the dissolved gas levels,** problems can be identified and evaluated further before they cause a catastrophic failure.

As seen in Table 1, **hydrogen gas** is clearly present in most fault types. As it is the first gas to appear and the only gas to be continuously present during thermal and electrical faults, hydrogen can be thought of as an early warning or "check engine light," alerting transformer operators to a potentially significant issue inside the transformer.

Moisture is another key factor affecting the dielectric strength and aging of transformer insulation. It is also an indicator for verifying the proper functionality of the oil protection system.

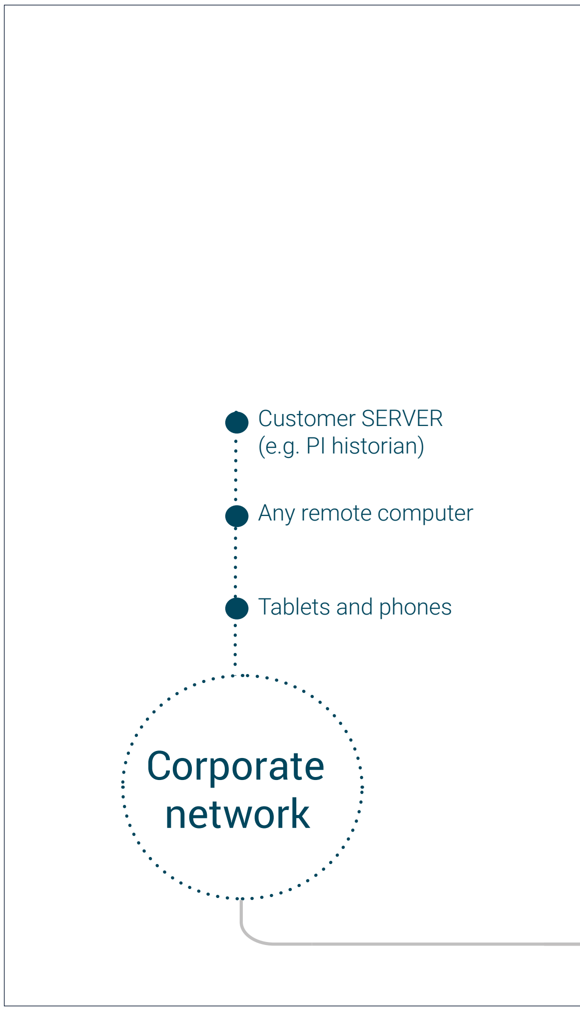
To have complete control of the thermal operation of the transformer, it is

Moisture is another key factor affecting the dielectric strength and aging of transformer insulation, which is also an indicator for verifying the proper functionality of the oil protection system

Table 1. DGA is based on the principle of the generation of different combustible gases depending on the temperatures reached by the oil.

Fault/gas generated	Carbon monoxide (CO)	Carbon dioxide (CO_2)	Methane (CH_4)	Acetylene (C_2H_2)	Ethylene (C_2H_4)	Ethane (C_2H_6)	Oxygen (O2)	Nitrogen (N2)	Hydrogen (H2)	Moisture (H2O)
Cellulose aging	+	+								+
Mineral oil decomposition			+	+	+	+			+	
Leaks into oil		+					+	+		+
Oil oxidation							+	+		
Thermal decomposition of cellulose	+	+	+				+		+	
Overheated transformer core	+	+	+						+	
"Thermal faults in oil (150°C to 300°C)"			+		Trace	+			+	
"Thermal faults in oil (300°C to 700°C)"			+	Trace	+	+			+	
"Thermal faults in oil (>700°C)"			+	+	+	+			+	
Partial discharge			+	Trace					+	
Arching			+	+	+				+	

Self-dehydrating breather type eSDB



*MeDICA offering includes 1, 5 and 9 gas analyzers necessary to monitor the temperature because high **temperature** causes transformer aging. Transformer mineral oil can degrade when exposed to heat, oxygen, and moisture.

Predictive maintenance

If you could predict the future, you might be able to plan better, make your maintenance plan more effective, and avoid transformer failure that could cause a serious impact on your business.

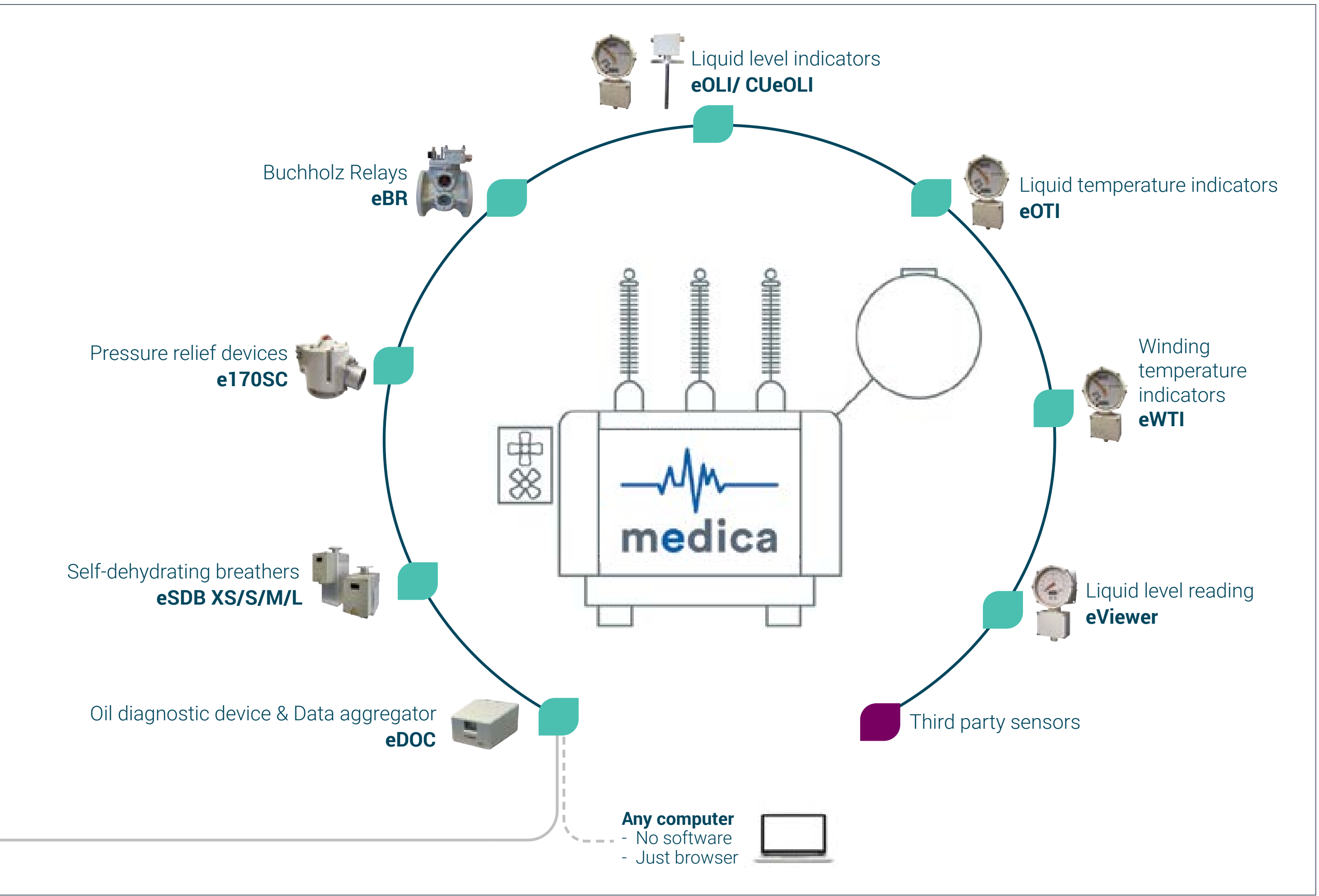
It is possible to collect data required for transformer health management remotely or on-site. By integrating and interpreting data from online monitoring and offline testing from the past and from today, we can spot patterns and see trends to better predict and forecast the future health status of the asset.

By integrating and interpreting data from online monitoring and offline testing from the past and from today, we can spot patterns and see trends to better predict and forecast the future health status of the asset

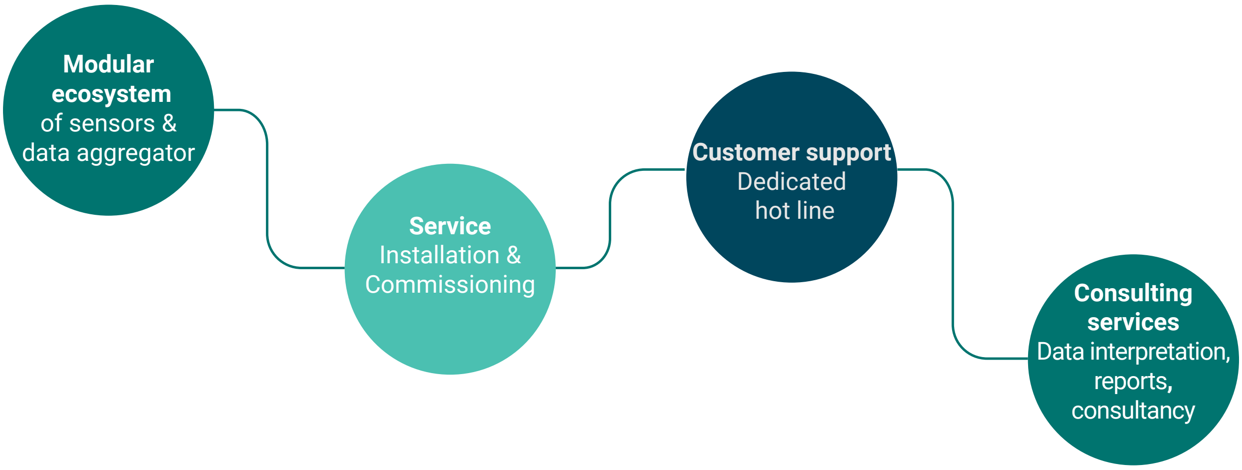
If you are looking for a relatively economical digital monitoring solution with an immediate effect on both operation and maintenance without complicating the data flow too much, choose our **Oil diagnostic device type eDOC, a single gas analyzer.** It continuously measures the presence of moisture and hydrogen in transformer oil and enables you to make informed decisions about asset maintenance needs. Thanks to this basic monitoring solution, the operation of the transformer is enhanced with detailed control of the thermal balance, the overload capacity, and the aging of the main insulation. As part of our MeDICA solution, it can also serve as a bridge to all other connected eDevices (Data Aggregator).

To perform a more detailed diagnosis almost in real-time and to take advantage of a wide range of services embedded in the MeDICA offering, combine the **Dissolved Gas Analyzer/Data aggregator* (1, 5, or 9 gas)** with at least one sensor from our eDevice family (self-dehydrating breather, pressure relief device, Buchholz relay, liquid level indicator, liquid and/or winding temperature indicator).

MeDICA is the right solution for the digitalization of transformers, both new



MeDICA is the right solution for the digitalization of transformers, both new applications as well as retrofit solutions for the existing installed base



applications as well as retrofit solutions for the existing installed base.

Together, **we** can build a proper transformer maintenance strategy based on a data-driven preventive and predictive maintenance program, increase the lifespan of your asset, and optimize your maintenance costs.

COMEM Service can help you with:

- Offline measurements
- Installation & commissioning
- Data interpretation, reports, and consultancy
- The provision of a user-friendly ecosystem with an embedded web interface & a common communication protocol.

Contact us, and our on-field team of experts will take care of your request during the entire project lifecycle, from the product selection to the installation, commissioning, and after-sales support.

We provide a wide range of solutions for different applications and installations in special environments, from offshore and marine to seismic areas.

Choose **MeDICA** and get a complete customer solution that includes products and services that can enable a longer and more efficient transformer life cycle.

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SCAN ME

Contact us & get support with the product selection:
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Oil diagnostic device type eDOC

Digital solutions for future grid complexity – The change in the grid forces the adoption of digital solutions to manage future complexity

ABSTRACT

Siemens Energy's presentation at the 2023 Transformers Magazine conference emphasized the role of digital solutions in addressing changes in the energy industry, including integrating renewables and managing complex grids. Their digital grid team focuses on implementing software-defined energy infrastructure using IoT and cutting-edge technologies, with solutions like Sensformer® offering real-time asset management and integration capabilities for improved operational decisions.

KEYWORDS:

digitalization, digital solutions, renewable energy, sustainability, grid management, IoT technology, asset management

Various challenges in today's markets can be tackled using digital solutions, such as enhancing transparency and optimizing asset management capabilities

The industry is undergoing a profound transformation with the increasing integration of renewable energy sources like wind, solar, and hydroelectric power

Introduction

During the 2023 Transformers Magazine conference in Dubrovnik, Tarik W. Radwan and Steffen Appel from Siemens Energy introduced the omnipresent topic "digitalization in the energy industry".

The presentation shed light on ideas concerning the sustainability and digitalization of energy assets and explained the current strategy and vision on how to support Siemens Energy customers.

"The change in the grid forces the adoption of digital solutions to manage future complexity": everyone talks about digital solutions, but nobody really knows when exactly to apply them.

Various challenges in today's markets can be tackled using digital solutions, such as enhancing transparency and optimizing asset management capabilities. At Siemens Energy, our mission is to guide our customers towards a more sustainable and digitally advanced future. As a reliable partner, our digital grid experts are committed to assisting in the implementation of a modern, software-defined energy infrastructure, empowering them to operate their grids autonomously and sustainably.

Breaking down the statement above, three main aspects should be discussed:

1. Change in grid

The industry is undergoing a profound transformation with the increasing integration of renewable energy sources like wind, solar, and hydroelectric power. This change introduces a fresh challenge: dealing with intermittent and unpredictable energy generation patterns. Organizations need to connect and manage various grids across regions and countries to balance supply and demand in the most efficient way. Gone are the days of unidirectional energy flow: the modern grid manages multi-directional flows, including energy storage and prosumers.

2. Future complexity

The increasing complexity in managing power grids underlines the importance

of making faster and more accurate decisions. Therefore, gaining and maintaining digital control becomes increasingly crucial, ultimately supporting the transition from a human-led model to a more automated and decentralized digital control system, thus enabling, for example, faster data flows and communication, real-time observability, and reduced human errors, decentralizing digital support leads to quicker decision-making. This progression eventually aims to enable faster and more efficient monitoring and control of power systems.

3. Digital solution

Through digital solutions, data is collected, analyzed, and utilized for data-driven decision-making and enhancing operational efficiency. Various analytics tools are utilized to detect failures, identify trends, predict future scenarios, and simulate key performance indicators.

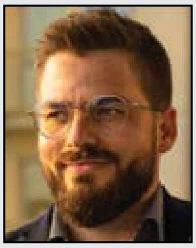
Siemens Energy's digital grid team aims at implementing modern, software-defined energy infrastructure, empowering customers to manage their grids autonomously and sustainably

Additionally, digital applications assist operators in scheduling maintenance at optimal times and enhance asset performance.

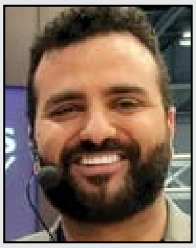
Siemens Energy's digital grid team aims at implementing modern, software-defined energy infrastructure, empowering customers to manage their grids autonomously and sustainably. Since 2018, they have been developing their expertise in IoT and edge technology to facilitate the transition towards net-zero emissions. IoT and Edge technologies provide transparency and asset management through a diverse array of advanced applications. Our team of experts develops and delivers asset management solutions that transform assets into real information hubs, enhancing overall reliability, customizing maintenance plans based on real-time asset conditions, and optimizing asset performance.

Just to name one of our solutions, Sensformer® is the complete asset management answer for your power transformer, which can provide you with all necessary information in real-time to make informed operational and maintenance-related decisions. **Sensformer®** provides automated alarm notifications based on pre-set alarm thresholds, allowing you to take action if and when required. Connected to the **Sensproducts** platform, you can drive your asset's performance and reliability and integrate with any third-party software via our API (Application Programming Interface) functionality.

Authors



Steffen Appel is a versatile professional with a master's degree in economics, boasting expertise in project management, business development, software development, and IoT. As a Product Manager for Asset Performance Management Applications, he supports cross-functional teams, delivering innovative solutions that drive growth and success within the Energy Industry. Outside work, he enjoys outdoor activities and sports.



Tarik Radwan commenced his journey with the Service Business for Power Assets at Siemens Energy, in 2015, based in Brazil, where he has specialized in Transformer Lifecycle Management. Passionate about Primary Equipment, he has been instrumental in shaping today's technologies to meet the ever-increasing demands on maintenance strategy, performance optimization and grid resilience. Tarik successfully spearheaded the launch and market entry of Siemens Energy's Sensformer solution in the Americas. Currently, he leads Siemens Energy's IoT & Edge global sales initiatives and go-to-market strategies.

Decarbonisation, Decentralisation, Democratisation & Digitalisation - Fighting fire with innovation

ABSTRACT

Addressing global warming requires innovative engineering solutions. The four megatrends: Decarbonisation, Decentralisation, Democratisation, and Digitalisation (the 4Ds) are crucial. Decentralisation emphasises localised energy resources, with Digitalisation ensuring automated grid management in response to variable renewable energies. Hitachi Energy's TXpert Ecosystem provides advanced transformer monitoring for grid reliability. In this technological age, merging domain knowledge with digital solutions is vital for sustainable energy management.

KEYWORDS:

4Ds, Grid management, Sustainability, Energy transition, Variable renewable energies (VREs), Decarbonisation, Innovations

Andrew COLLIER, Carlos MARTIN

Decarbonisation, Decentralisation, Democratisation, Digitalisation: The 4Ds revolutionising our fight against global warming

> **Millions of electric vehicles plugged into the power grid could also be part of the energy storage solution**

Engineers could lay claim to creating fire, or maybe boiling water to create steam, which in turn drove the steam engines of the 1st Industrial Revolution and today forms the motive force for the steam turbines that are at the heart of many bulk electrical power generation.

As engineers, we are great at finding new ways to solve problems, but when we consider the amount of fossil fuels burnt to generate electricity, we are now in a situation where we need to solve what could be humanities greatest challenge - a challenge we have in part created, the challenge of Global warming.

A large part of the solutions to global warming are the four Mega trends of Decarbonisation, Decentralisation, Democratisation and Digitalisation, commonly referred to as the 4Ds. The need for Decarbonisation is not new, but the rate of change needed is, and while Variable Renewable Energy resources (VREs) are increasingly attractive to investors, these technologies bring their own challenges. One advantage VREs have is that they open the door for more decentralisation and democratisation of the electricity generation market, but with these things come high levels of complexity and volatility, so it is now also accepted we can only achieve these things while maintaining or increasing system stability and reliability through the use of extensive Digitalisation.

Starting with Decarbonisation, this remains the primary goal. Most people accept this and the consensus that we need to move to a carbon-neutral energy system but struggle with the sheer scale of changes needed, which are much easier said than done and will require both additional grid infrastructure and modernisation.

The electrical power grids have slowly evolved in most countries over the best part of a century. However, most will now need to change more in the next 10 years than they have over the last 100. The Sankey diagrams in Fig. 2 are intended to help visualise the changes to both energy source and use, with the left-hand side of each column representing the source and the right-hand side the use. As of 2020, circa 20% of global energy use was via electricity, and only circa 2% came from variable renewables. By 2050, electricity generation will need to grow to at least three times that of 2020, and we will need to utilise 50% of our energy use via electricity. Furthermore, the (variable or some may say volatile) renewables part will need to increase 20-fold. This will need to include utility-scale generation, but one of the advantages VREs bring is their ability to be applied at a smaller scale en masse.

Renewables are great, and we want to integrate as much of them as possible, but this is not without its challenges. The first of which is where much of it will be physically located.

Decentralisation - For the first 100 years of the power grid, the focus has been on bulk power generation, with those large generating stations often quite far from the load centres. The 4th industrial revolution is already here, and with it, a focus on connectivity and networking. Power grids are increasingly "inter-connected"; however, power still mostly flows in a

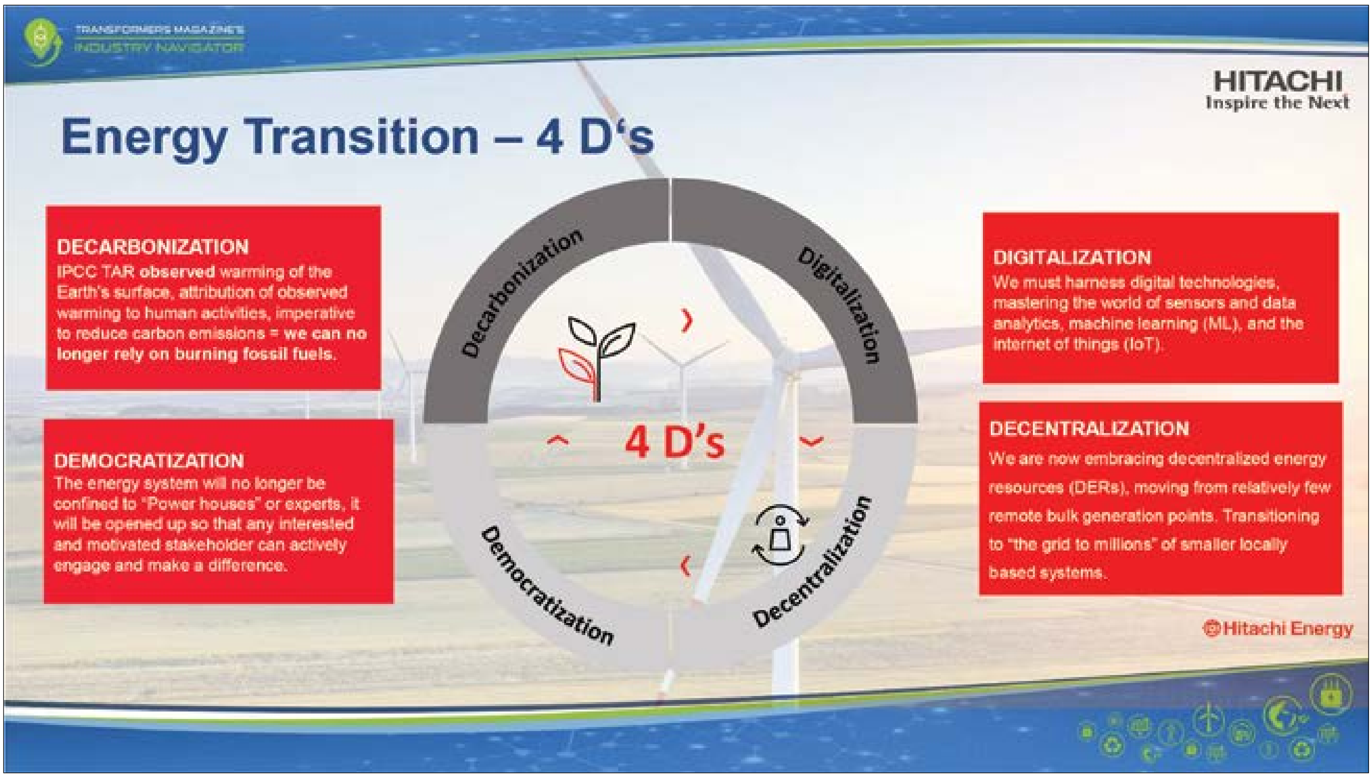


Figure 1. The four Ds of the Energy Transition

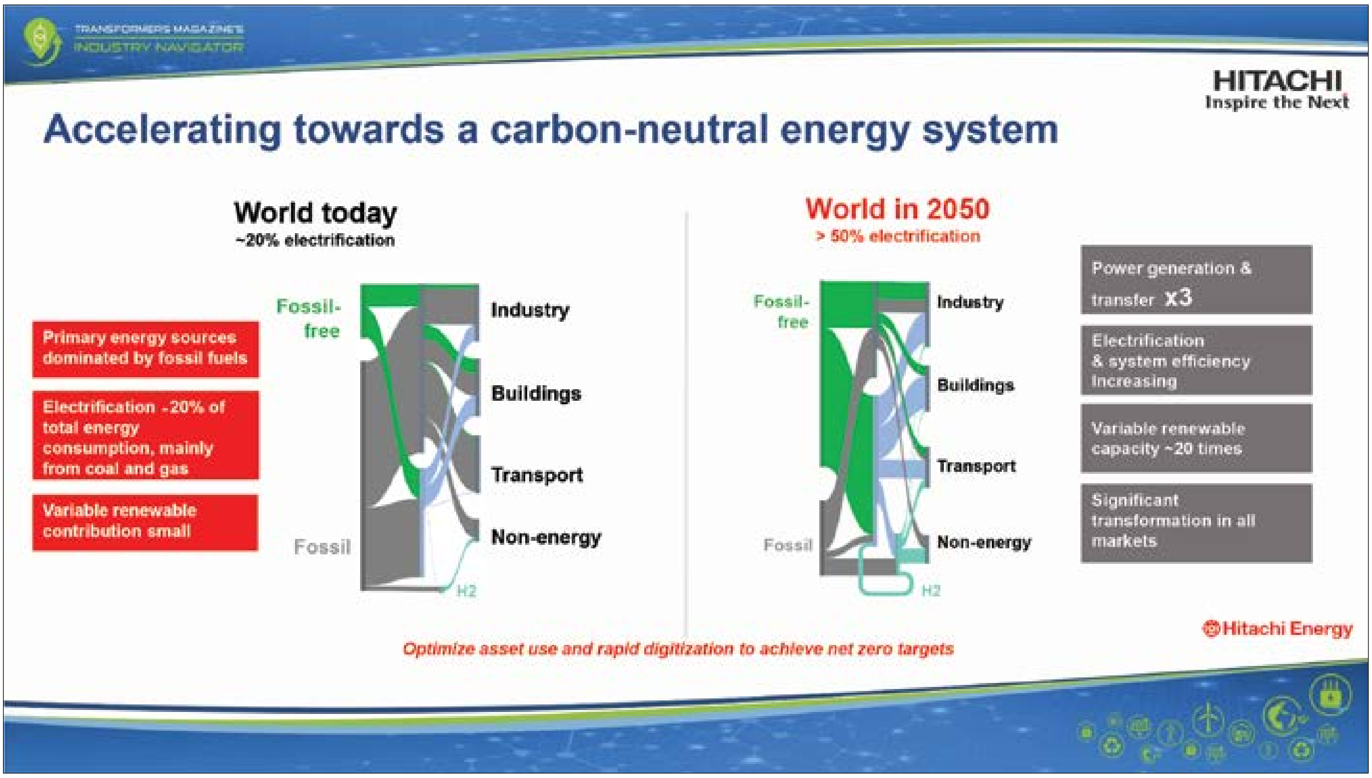


Figure 2. Rapid Digitalisation to Achieve Net Zero

unidirectional, top-down, bulk power to-load centre manner. With the addition of distributed energy resources, many of these can be installed locally, and the recent Fraunhofer "Photovoltaics Report" [2] highlights there are already more than 2 million Solar installations in Germany, which supplied 9.9% of Germany's energy (in 2021).

The future grid architecture will take a huge investment, both in new infrastructure and existing infrastructure updates.

Today, the circa 2% of variable renewables we do have are not evenly distributed across the world. We still mostly have bulk power generation, and where we do already have VREs in play, we are seeing changes in the way the Grid needs to operate to accommodate the differing power

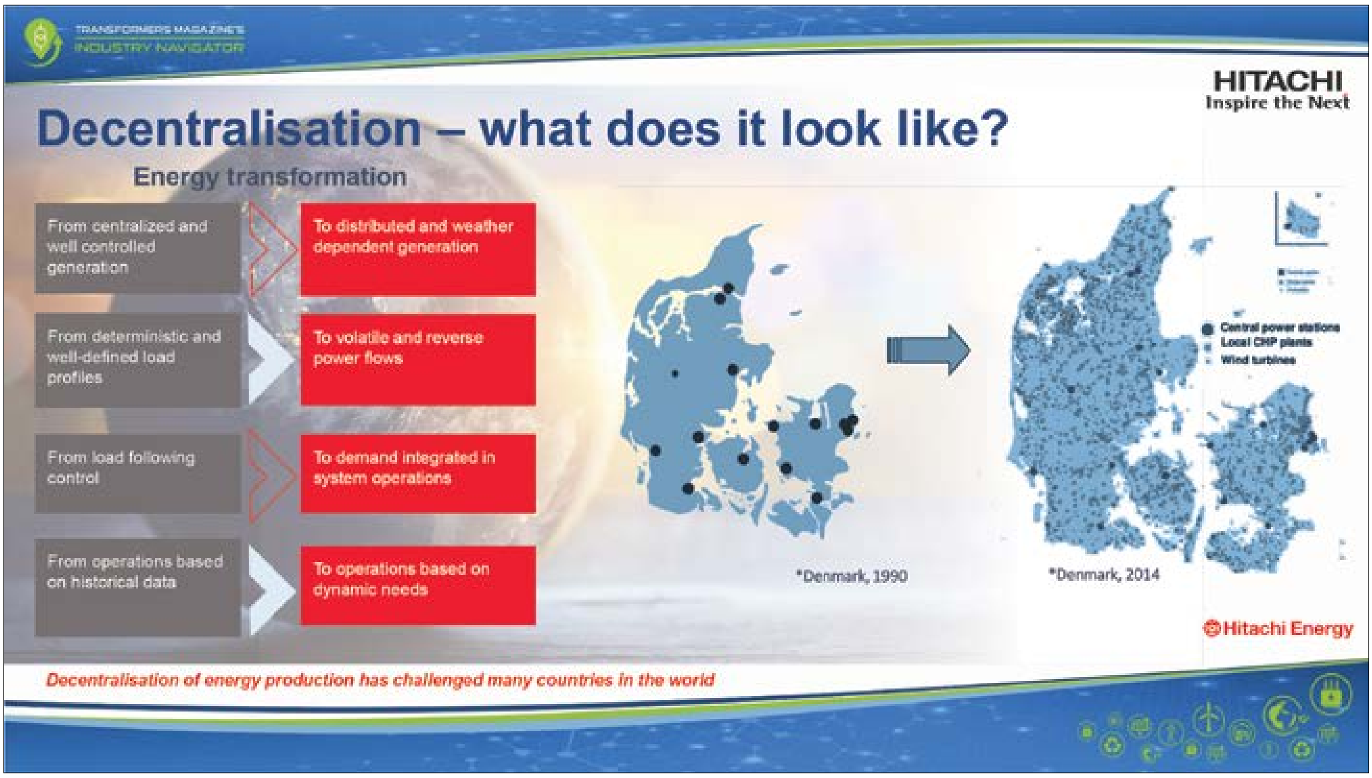


Figure 3. Decentralisation example from Denmark

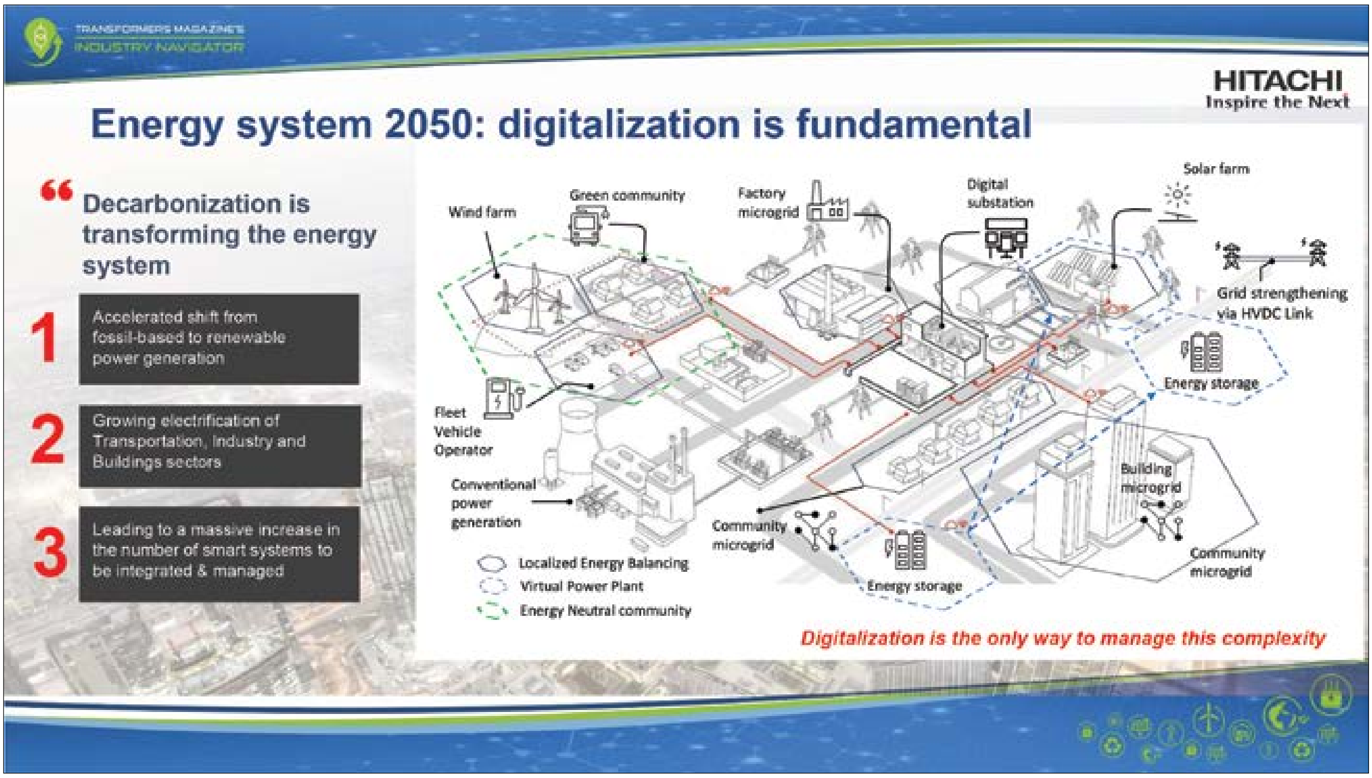


Figure 4. Energy System Vision 2050

The challenge ahead of us is to maintain or improve grid reliability in times when we are facing aged infrastructure, increased demand, extreme weather events and semi-conducting equipment

flows at different times of the day or night. Independent of ambition levels for the switch to wind and solar-based energy sources, in practical terms, there are limits to how quickly the transmission system can be expanded to accommodate utility-scale projects. There is, however, a significant scope to grow smaller-scale local production and consumption. In the vision for Energy System 2050 (Fig. 4), we can illustrate how local networks made up of Virtual Power Plants, Prosumers and local energy storage form micro-grids can help to balance out the peaks and troughs. There are currently challenges in integrating any new supply sources into the power grids (and bidding on supply contracts).

This is, however, changing and independent of the technological challenges we are now seeing in governmental initiatives such as the EU's Green Deal and new legislation such as FERC 2222.

Electrical vehicle charging is mostly seen as a burden. However, with even a small area such as the United Kingdom set to have 10 million vehicles with a plug by 2030, these could also be part of the energy storage solution while at the other end of the geographical scale, even in the USA, we are now seeing the Bipartisan Infrastructure Law, with cross-party support for President Biden's goal to reach a carbon-free electricity sector by 2035.

Through the great work done by independent bodies, such as Cigre, we can see that monitoring provides the potential to identify developing problems at an early stage

Technology is already omnipresent in many parts of our lives, and we are all now on some form of digitalisation journey. This can mean different things to different people, so for the Digitalisation of the power grid, we can think in terms of Automatisation, i.e. automated collection, analysis & interpretation.

Power grids and power transformers, in particular, are impacted by the changes in the grid dynamic, with power flowing in different directions and the potential for increased voltage levels. They are also subjected to changes in weather patterns and some of the extreme weather events that are currently increasing in both frequency and severity. The challenge ahead of us is to maintain or improve grid reliability in the face of ageing infrastructure, increased demand, extreme weather events and an increasingly semiconductor-based generation mix. Power transformers are supplied against demanding requirements and specifications, but they can be exposed to many external "events" over their lifetime. These are often not well documented, and ultimately, a relatively small event can result in a failure in an already weakened transformer. Today, it is more important than ever before to "observe" how your fleet is being utilised.

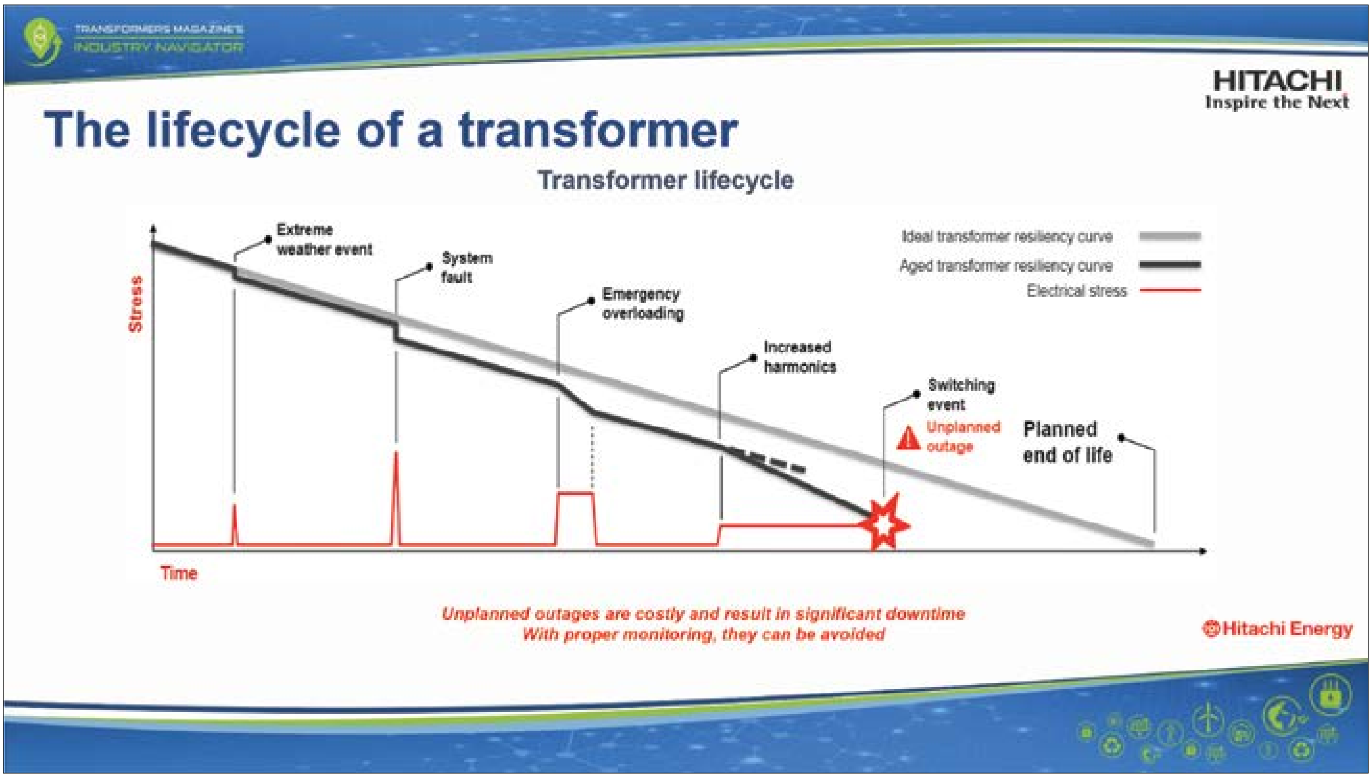


Figure 5. Impact of external events over time

Through the great work done by independent bodies such as Cigre, we have good historical insights into both failure locations and failure modes [3]. We can also see that monitoring provides the potential to identify developing problems at an early stage. Documents such as TB642 [3] are a great independent source of information, where industry experts estimate that monitoring could help in the early identification of a developing fault, significantly reducing the lost revenues and repair costs [4]. Not to mention the risks to the environment should a catastrophic failure occur.

Monitoring or Digitalisation is itself not without its challenges, and already, we are globally generating 2.5 billion gigabytes of data every day [1], half of which organisa-

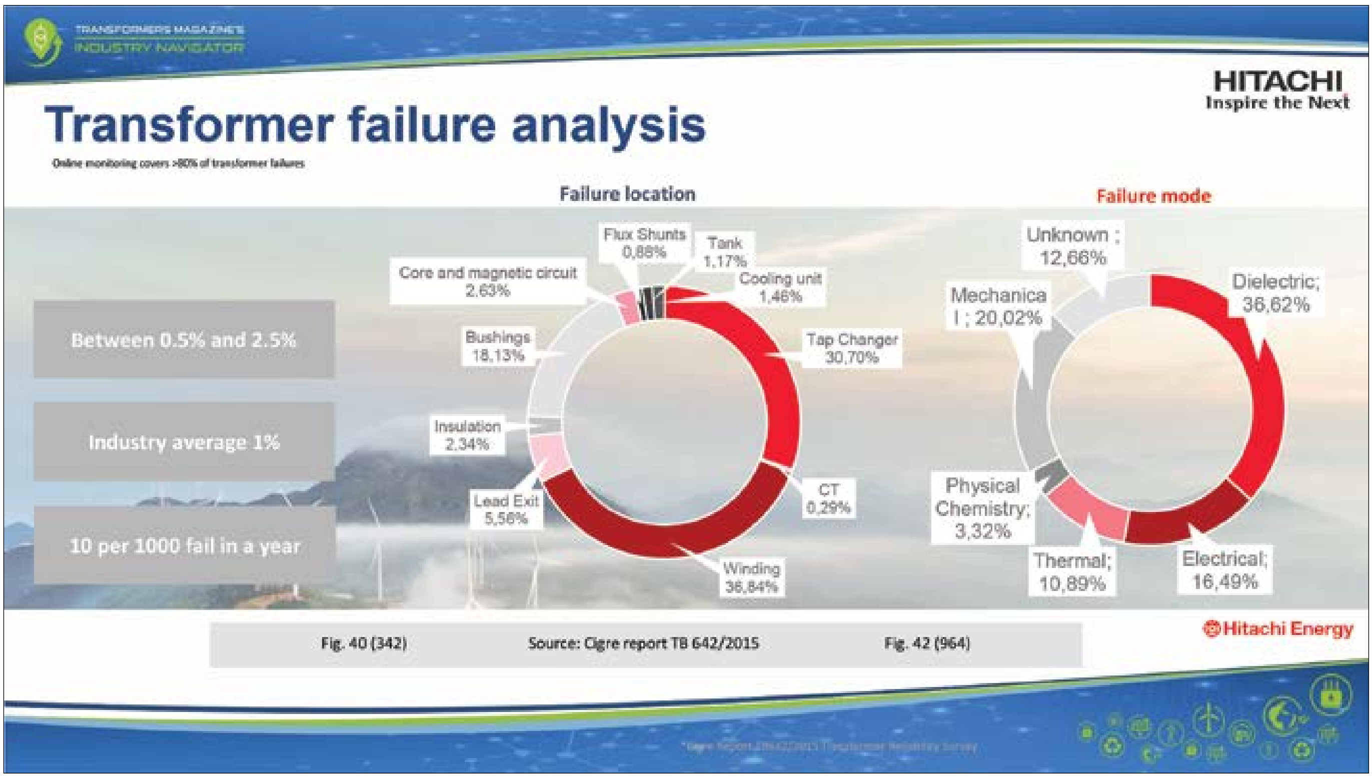


Figure 6. Failure mode and location

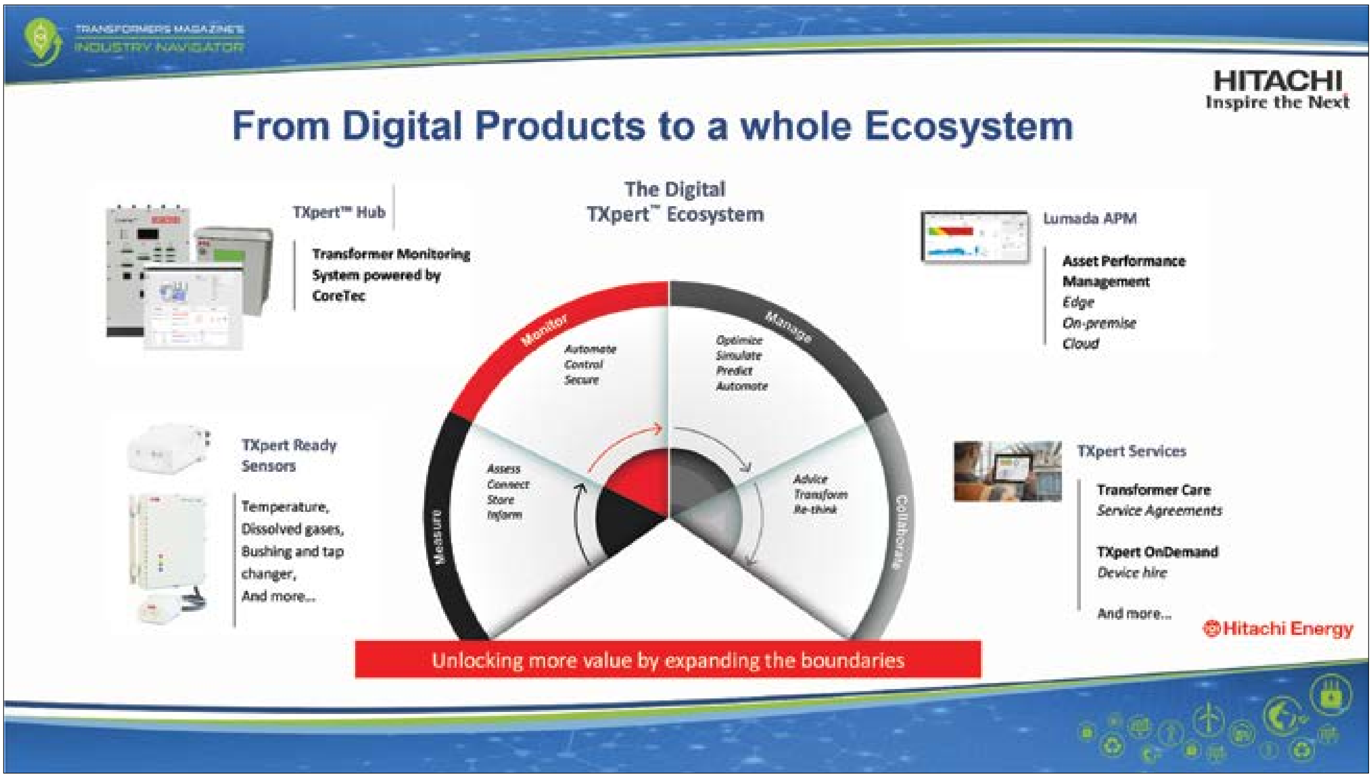


Figure 7. TXpert™ Ecosystem

> **The scalable and modular Ecosystem allows you to prioritise where to start your Digital journey while providing guidance and safety in the knowledge**

tions are struggling to find or fully utilise. If we are to achieve sustainability, we need to decarbonise. If we are to decarbonise (and we must), then we need useable Digital insights if we are to maintain a reliable power grid. Hitachi Energy has a long and strong history, with domain knowledge encompassing legacy brands such as ASEA, BBC, Stromberg, Ansaldo, Westinghouse and many more. We have also been providing state-of-the-art transformer monitoring systems for more than 20 years, culminating in the Hitachi Energy TXpert Ecosystem. This is an open, modular, scalable and future-proof system with the same way of working across transformers that can be new or old, liquid-filled or dry and is manufacturer agnostic. It covers much more than just devices, including asset performance management (APM) & Services.

The Hitachi Energy TXpert™ Ecosystem has evolved to combine not only world-leading domain knowledge (with historical design data and more than 10,000 transformer assessments) but also includes the integration of customers' preferred Smart Sensors, via the TXpert Ready program, whether that be DGA, Bushings or whatever else individual customers consider important.

Well-intentioned, time-based inspections are sadly only ever a snapshot of a moment in time and can only indicate current status or where some new threshold has been achieved since the previous visit. Warning signs can themselves be a combination of thermal, electrical, mechanical or chemical. The scalable and modular Ecosystem allows you to prioritise where to start your Digital journey while providing guidance and safety in the knowledge. It can be expanded should your future needs change. In the example from Fig. 8 the technicians were able to identify the increase in hydrogen generation coincided with an increase in temperature at a time of stable loading. This brought the (water) cooling system into question, where a mineral buildup was found to be blocking the heat exchanger.

With the increase in the adoption of VREs and the impact these are having on loading profiles and the time needed to replace existing infrastructure, it will be increasingly valuable to be able to understand better the reserve capacity of individual network elements under dynamic conditions. In the example from Fig. 9 a customer would be able to access and could then utilise the insights into the hotspot temperature and reserve capacity, should they need to apply dynamic loading when facilitated by suitable ambient conditions. Note: It is important to note that an increase of only 7°C can double the ageing rate of the transformer insulation.

Historically, monitoring has been deployed sporadically and mostly retrospectively, triggered by events or changes in policy. This has resulted in many "silos" of information typically working in isolation, even if they are actually connected to some upstream system. Whether your starting point is adding an electronic temperature module (ETM) to new Transformers or DGA sensors to the installed base, continuous (online) monitoring provides "in operation" insights to complement whatever offline testing program you may have. The sooner you start, the better off you are, as anybody attending a site with a tripped transformer is essen-

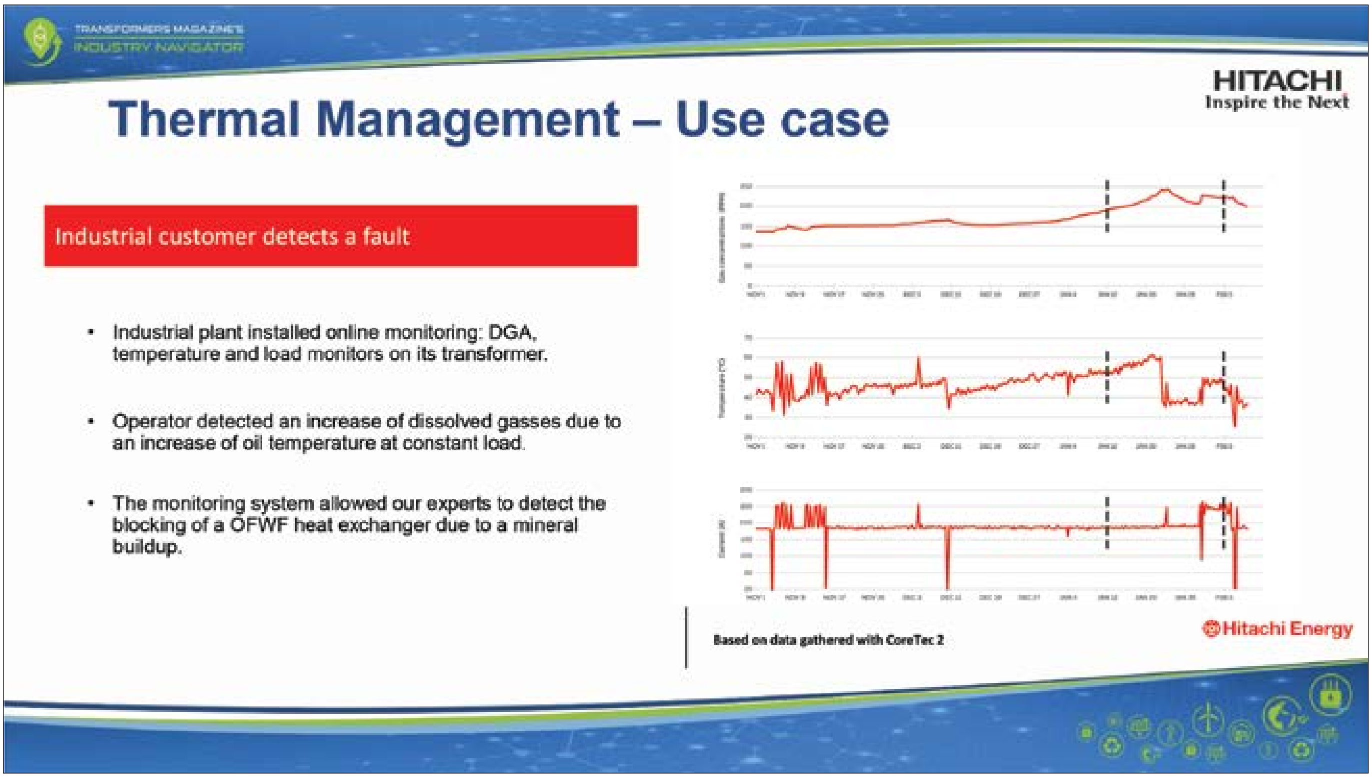


Figure 8. Example illustrating the case of a blocked cooling system.

tially a detective, arriving hours or even days after the event into circumstances that have almost certainly changed in some way, shape or form.

The TXpert Ecosystem brings together these varied but important transformer

Historically, monitoring has been deployed sporadically and mostly retrospectively, triggered by events or changes in policy, but there is a better, wiser way

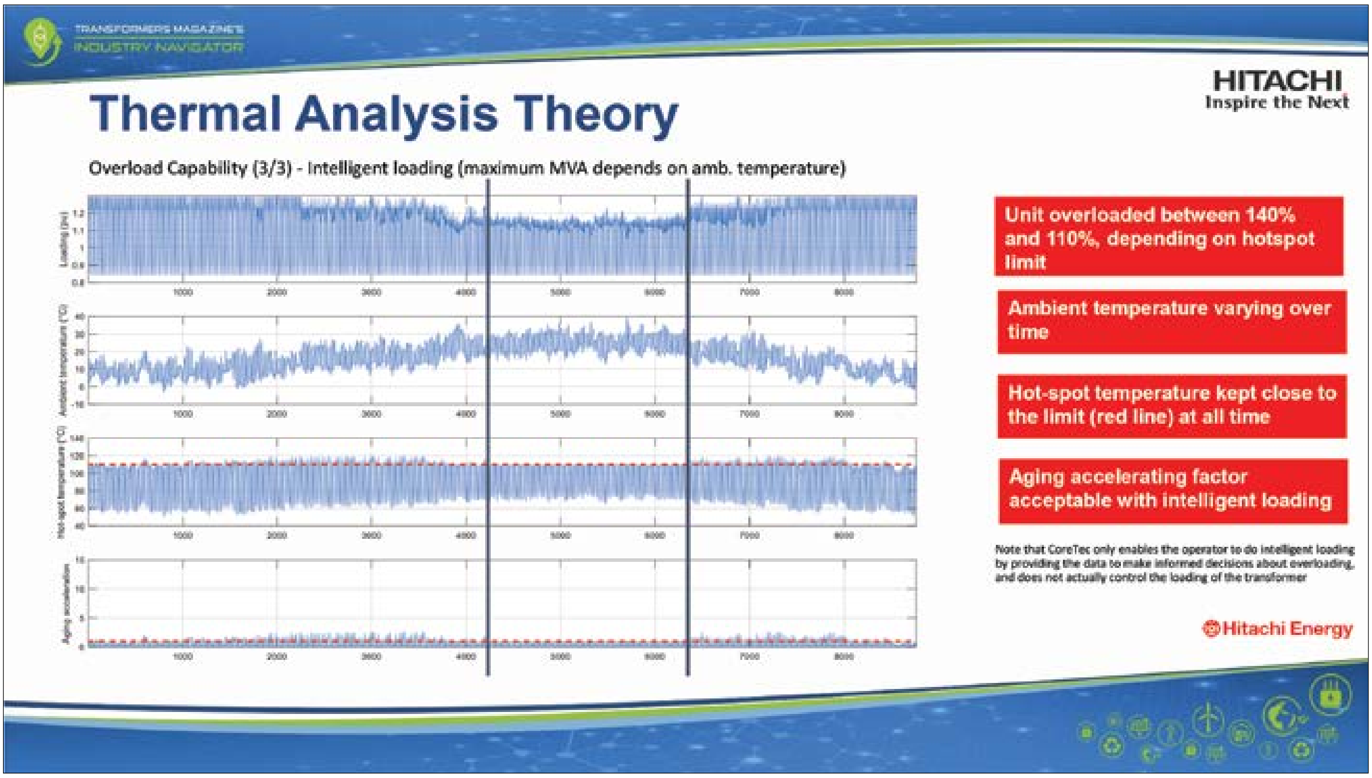


Figure 9. Illustration of hotspot temperature in relation to load and ambient conditions.

The TXpert Ecosystem brings together important transformer health parameters and includes a browser format of User Interface to ensure ease of use and provide application dashboards and insights

health parameters and includes a browser format of User Interface to ensure ease of use and provide application dashboards and insights. These are available via laptop, remotely or via a locally mounted 7" touchscreen. Multiple "industry standard" based representations (Fig. 11) are available for areas such as analysis of the dissolved gasses. Customers can also select their own preferences for trending graphs, spider chart limit values and other health indices.

The monitoring, local storage and visualisation of individual on-asset information is valuable in isolation and is the enabler for more powerful Asset Performance Management (APM) tools, whether that be for multiple transformers at the sub-station level via the APM Edge or Enterprise-wide solutions for different key asset types via Lumada APM. The more powerful software tools utilise the same look and feel as the on-asset aggregator interface. However, they provide the opportunity to add off-line information such as standard oil tests and can provide probability of failure information, prognostic insights and facilitate condition-based maintenance (CBM) programs.

On-asset information and visualisation support those physically on site. However, Remote services can be utilised to access the global skills and guidance of domain experts to support both day-to-day activities and in the event of a problem. Connected assets bring significantly more value and improve efficiency, but they also represent additional exposure to cyber threats. Cyber security should be approached in a similar manner to traditional security, i.e., it is important for organisations to restrict access to devices, just as they do high-voltage equipment. It is also paramount to work with providers who offer both cyber-certified products and associated development organisations [5, 6]. Furthermore, cyber security should be considered part of any organisation's license to operate, which can be complicated to apply as many organisations struggle to keep up with the fast-moving changes and may confuse standards such as NERC CIP (which relate to whole systems) rather than device-specific standards. For the monitoring devices themselves, the key standards are IEC 62443-4-2 [7] and IEEE 1686 [8].

Connected assets bring significantly more value and improve efficiency, but they also represent additional exposure to cyber threats

Wherever you are on your journey to benefit from the different areas, Digi-

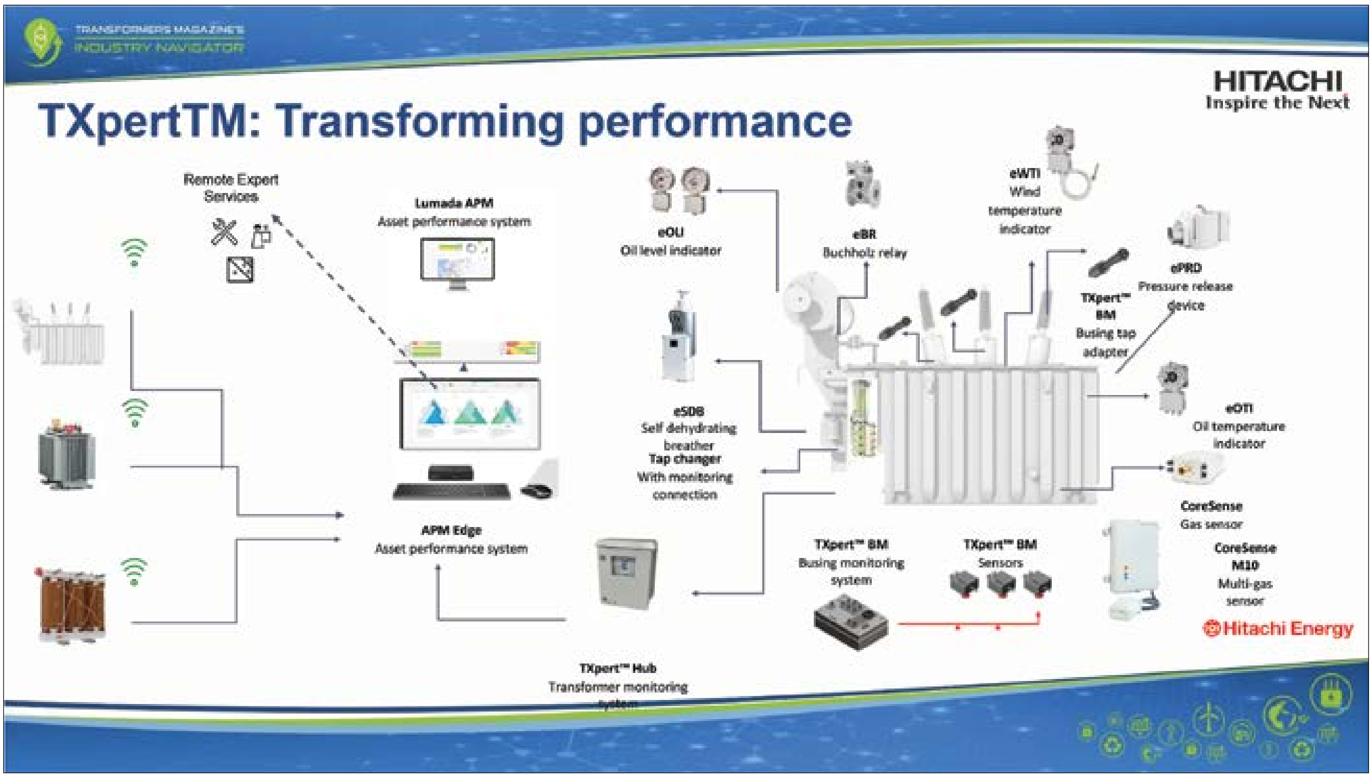


Figure 10. Combination and visualisation of multiple smart sensors

talisation can help you and your organisation. Hitachi Energy has the expertise in Transformers, in Digitalisation and Services. The team from Hitachi Energy are here to help you, whatever your area of need, whether that be sustainability, digitalisation or how digitalisation can help you achieve your sustainability goals.

At Hitachi Energy, our purpose is to advance a sustainable energy future for all, and we are delivering this through our pioneering innovation combined with our strong belief in the value of collaboration and tackling challenges together.

The Energy Transition that our planet now needs brings with it many challenges. To achieve our decarbonisation goals will require extensive investment in new electric power infrastructure, but this alone will not be enough. Digitalisation is the only way to manage this complexity and deliver the necessary visibility, agility and fast, data-driven decision-making across an entire business.

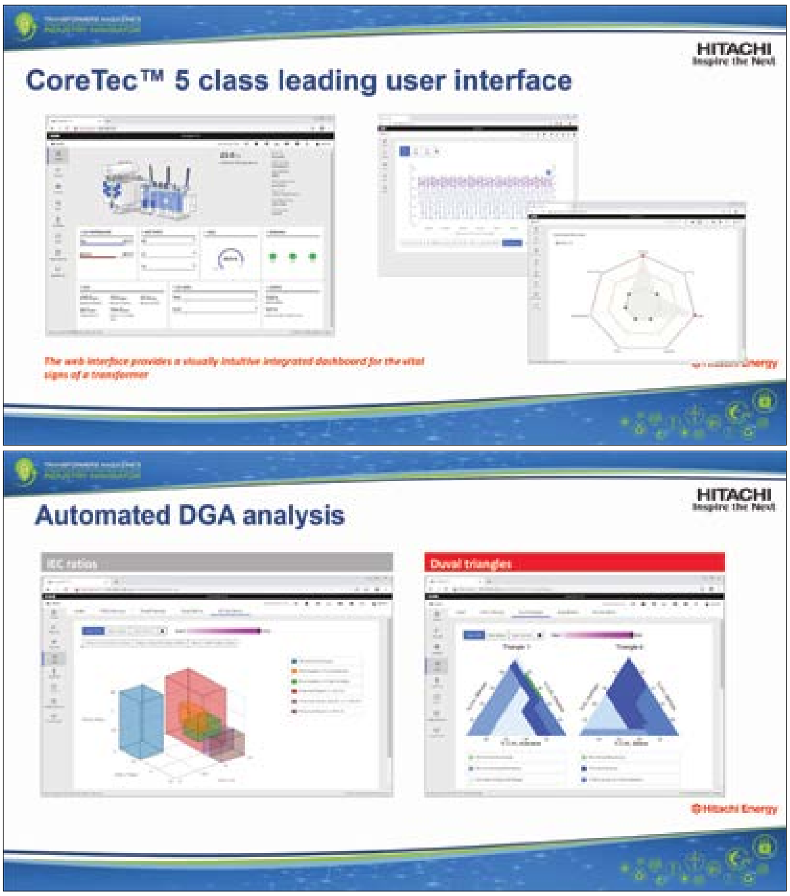


Figure 11. TXpert Hub, application Dashboards.

The team from Hitachi Energy are here to help you, whatever your area of need, whether that be sustainability, digitalisation or how digitalisation can help you achieve your sustainability goals

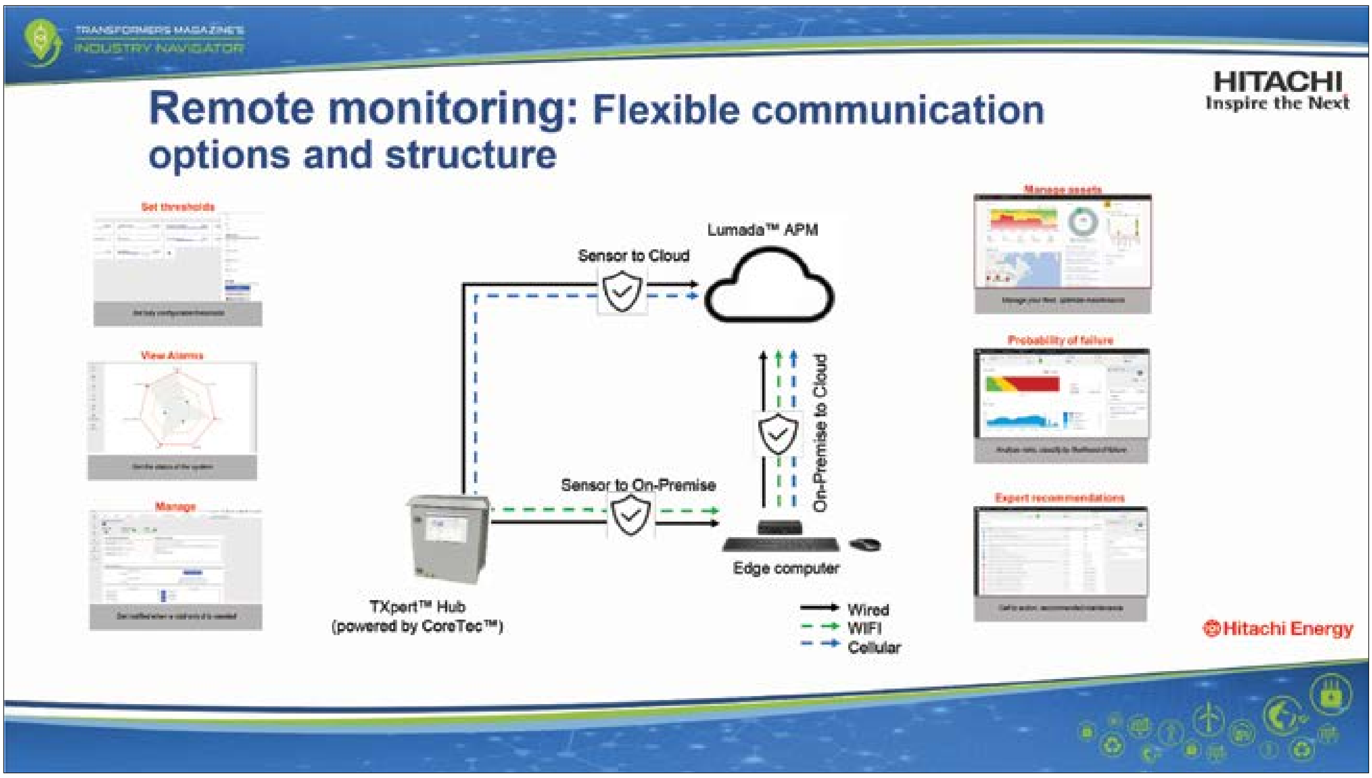


Figure 12. TXpert Hub, local and remote monitoring options

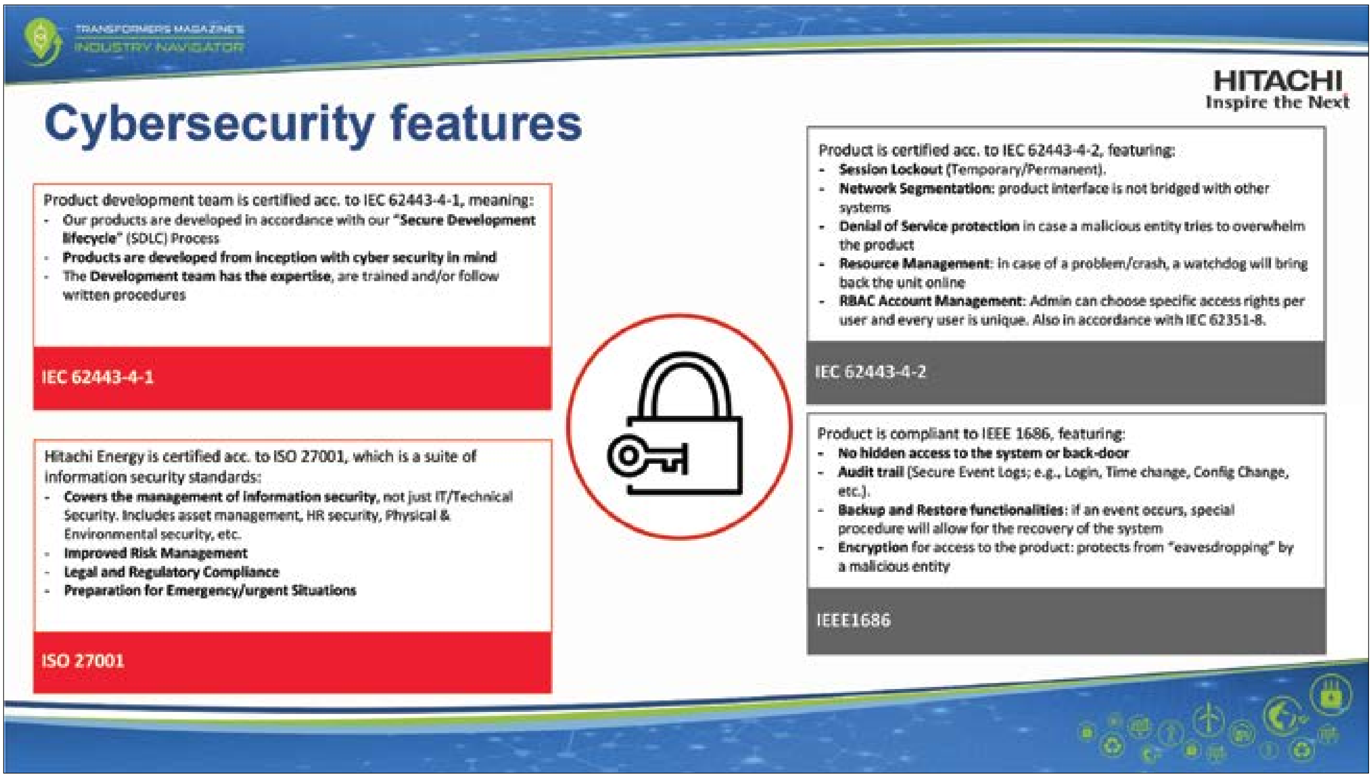


Figure 13. Cyber security considerations

Today, more than at any time in the history of generation, transmission and distribution, we need the benefits of domain knowledge and support of intelligent insights to ensure reliable grid operation – Join us to learn how Hitachi Energy's open, scalable and manufacture agnostic Ecosystem can bring you real-world benefits today, tomorrow and in the future.

[1] Source "Future Power Technology" magazine.

[2] Fraunhofer Institute for Solar Energy Systems, 2022 Photovoltaics Report

[3] Cigre Technical Brochure 642/2015 Transformer Reliability Survey

[4] Cigre Technical Brochure 248, Economics of Transformer Management

[5] IEC 62443-4-1:2018, Secure product development lifecycle requirements

[6] ISO/IEC 27001:2022, Information security management systems

[7] IEC 62443-4-2:2019 Technical security requirements for IACS components

[8] IEEE 1686:2022 Standard for Intelligent Electronic Devices Cybersecurity Capabilities

Authors

Andrew Collier graduated from the North Oxfordshire Technical College and then Oxford Brookes University, where he studied Electrical and Electronics Engineering together with Microprocessor based control systems. His work experience includes the positions of a Test Field manager and Senior Design Engineer before he moved into sales and marketing, where he has held international management positions for the last 19 years. He has been working in the transformer business for 15 years, and he is responsible for the digitalisation of the Hitachi Energy transformer business. Andrew has cowritten several whitepapers and codeveloped both patents and trademarks relating to the digitalisation of Transformers. As a keen scuba diver with over 25 years' of experience, Andrew has a real-life appreciation for the importance of protecting our planet.

Carlos Martín, originally from Granada (Spain), graduated from the University of Cordoba and Malaga University, where he studied Industrial Engineering. He also finalised a master degree in Business Administration at Solvay Brussels School of Economics and Management. He has been active in the Power Electricity sector for almost two decades, where he took various roles in different companies. In his current role at Hitachi Energy, he focuses on transformer applications to make our grids and industry more robust and sustainable. He is currently a member of CIGRE working group B3.41 on Mobile Substations Incorporating GIS.


Transformers
MAGAZINE

ABSTRACT

Digitalization - the subtle yet powerful force with a significant impact on the power transformer industry. We explore the practical applications of advanced digital technologies, from design and engineering to manufacturing and sustainability practices. In addition, the industry's efforts toward standardization and professional development through digital tools are discussed.

KEYWORDS:

digitalization, sustainability, engineering, manufacturing, advanced technologies, standardization, professional development

Collaboration towards digitalization of the industry
Source: By Yingyaipumi, Stock.adobe.com

Harnessing the power of digitalization in the transformer industry for sustainability

The potential of digitalization extends across various dimensions, encompassing design, engineering, manufacturing, and supply chain operations

Introduction

In recent years, the power transformer industry has witnessed a remarkable transformation with the advent of digitalization. Advanced digital technologies have permeated every aspect of the industry, from design and engineering to manufacturing and supply chain management. In this article, we explore the potential and impact of digitalization in the power transformer industry, highlighting its role in improving efficiency, reducing environmental impact, and enhancing overall performance.

Digital technologies reshaping the industry

The power transformer industry has embraced a suite of digital technologies that are revolutionizing traditional processes and systems. The modern compact substation (CS) is a complex system that relies on the reliable operation of all its power, measurement, and communication subsystems. These technologies include advanced sensing, machine learning, digital twins, big data analysis, and cloud computing. These tools have become indispensable in engineering research and development endeavors, exemplified by the initiatives at the SGB-SMIT Group. The cooperation and collaborations with diverse energy industrial partners and digital technology leaders would allow subsequent growth in the industry towards digitalization.

SGB-SMIT Group's transformers range from 25 kVA to 1200 MVA

The reach of digitalization

The potential of digitalization extends across various dimensions, encompassing design, engineering, manufacturing, and supply chain operations. By deploying harmonized performance-enhancing design tools and platforms, the industry can capitalize on synergies, streamline processes, and minimize human errors. Improved design efficiency, risk reduction, and sustainability successes that match with UN sustainability goals are some of the key advantages.

Coupling of engineering software would offer greater estimation capabilities. At SGB-SMIT Group, a successful implementation of electrical and CAD tools coupled with magnetic, thermal and mechanical finite element method (FEM) software has been proven to yield fruitful results. The days of solving complex electromagnetic/mechanical challenges are now reduced to only a few hours.

> **Sustainability is a key driver in the power transformer industry, and digitalization plays a pivotal role in achieving the objectives**

Sustainability at the core

Sustainability is a key driver in the power transformer industry, and digitalization plays a pivotal role in achieving the objectives. Digital tools facilitate material reuse, assess carbon footprints, reduce waste, and enhance control over dangerous substances. This optimization extends to manufacturing processes, reinforcing the industry's commitment to environmental responsibility.

Standardization efforts

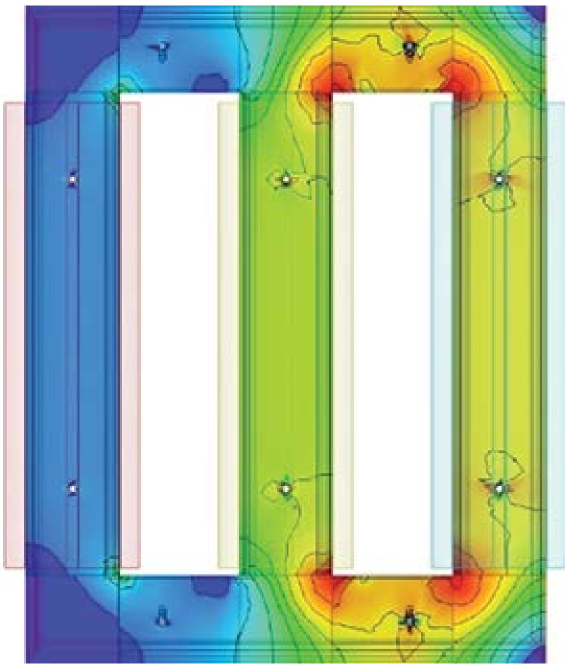
Collaborative efforts, such as the DNP project involving SGB-SMIT Group, are pushing for industry standardization. Digitalization not only improves operational efficiency but also aids in harmonizing performance across the organization. Streamlining manufacturing operations with digital tools, including simulations and digital prototyping, accelerates design iterations and ensures product excellence. Also, SGB-SMIT Group is deploying digitalization concepts in building an R&D project consortium to reduce transformer core power losses by 10 % using advanced laser magnetic domain refinement techniques. The role of consortium partners would not only be to develop necessary technological solutions associated with it, but also to implement digital concepts in all project phases while achieving them.

Digital twins and real-time monitoring

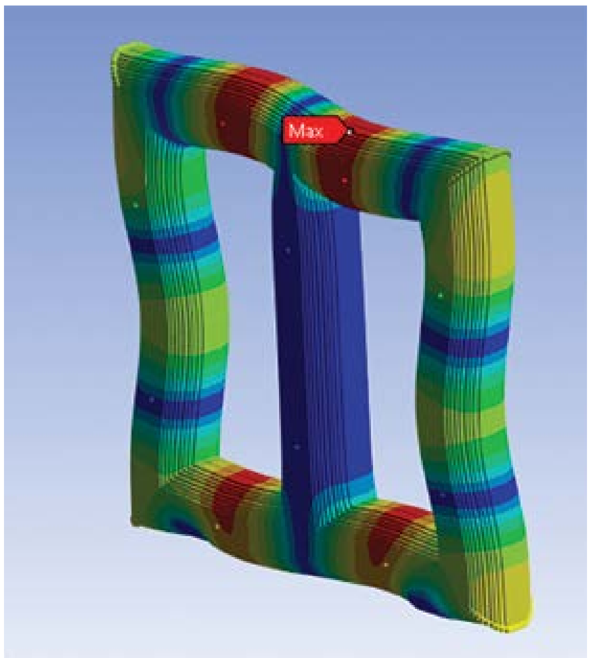
Digital twins enable the modeling of transformer behavior in real-world conditions, providing accurate predictions and simulations. Automation and real-time monitoring of manufacturing equipment, facilitated by sensors and robotics, boost efficiency while reducing costs. These advancements are essential for meeting the industry's growing demands.

Digitalization was the enabler of SGB-SMIT Group's transformer operating system. The operating system relies on extensive sensing for monitoring Temperature, hotspots, currents & voltages, etc. Calculation methods for losses, DGA, and noise were interfaced with a cloud-based communication system to effectively enhance customer situational awareness of transformer health.

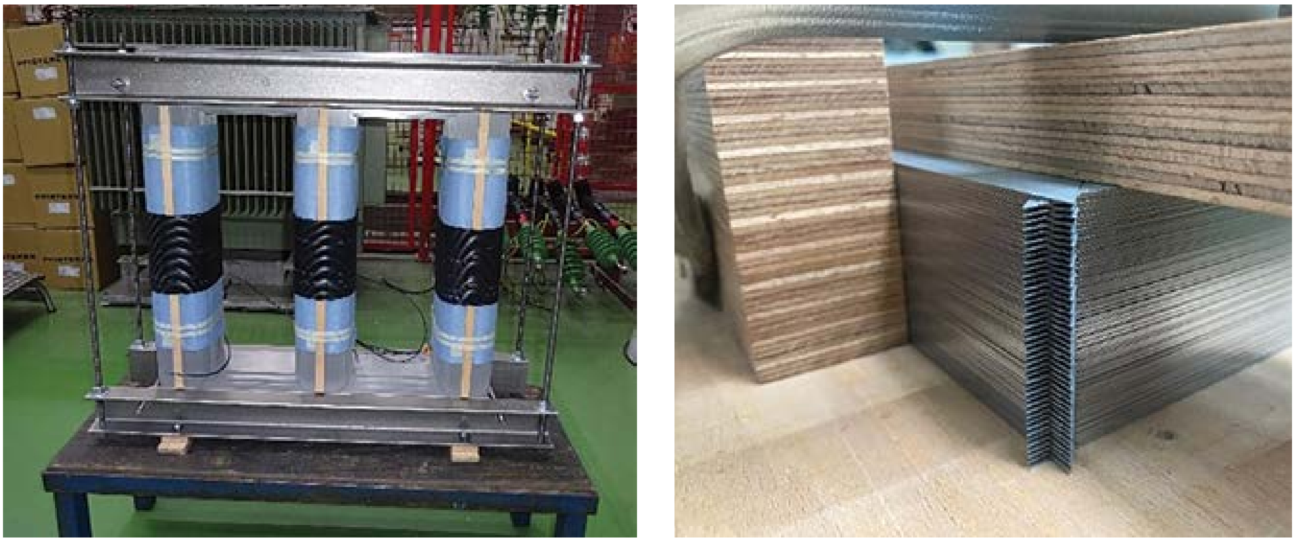
> **Digital twins enable the modeling of transformer behavior in real-world conditions, providing accurate predictions and simulations**



FEM magnetic simulation for core losses by SGB-SMIT Group's R&D



FEM mechanical simulation for core noise by SGB-SMIT Group's R&D



Laboratory scale experimental setups by SGB-SMIT Group to validate core losses improvement

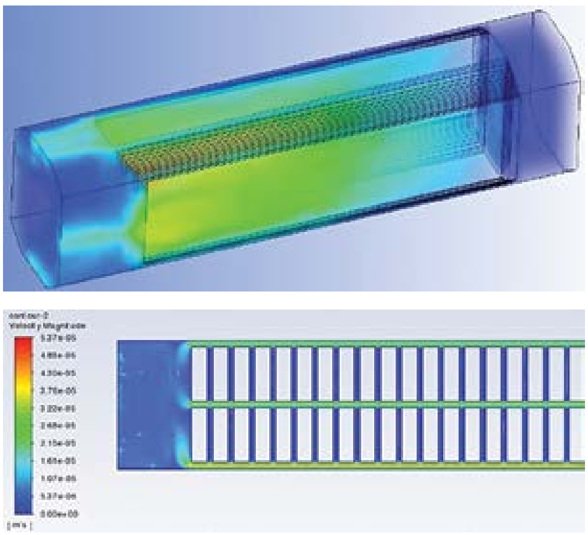
Modern sensors, real-time signal processing algorithms, 3D modeling, and augmented reality systems promise faster, more reliable results, reducing the need for extensive human resources

Enhancing partial discharge measurements

One significant research and development initiative by SGB-SMIT Group focuses on improving the accuracy and reliability of induced voltage localization with partial discharge (IVPD) measurements. Modern sensors, real-time signal processing algorithms, 3D modeling, and augmented reality systems promise faster, more reliable results, reducing the need for extensive human resources. The new framework would allow completing the measurements and obtaining high-fidelity results within 4 hours, which is a significant contribution in terms of speed and accuracy compared to the conventional measurement setup.

Exploring alternative materials

Digitalization is instrumental in exploring alternative materials for transformer insu-

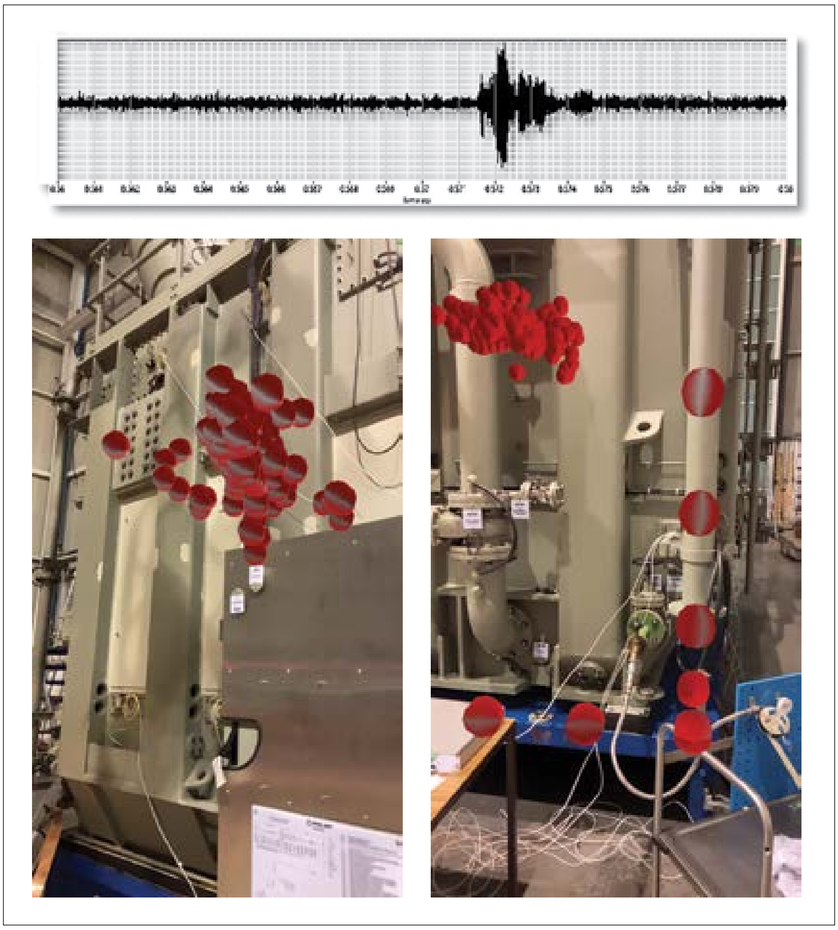


Visualization of Computational Fluid Dynamics (CFD) simulation capabilities adapted in the SGB-SMIT Group's operational R&D activites

SGB-SMIT Group's transformer operating system visualizes the real-time measured data of power quality, losses, and temperatures

SGB-SMIT Group, a global player in the transformer market with 14 manufacturing plants, is leveraging digitalization in electrical design

lation. The adoption of new bio-based, biodegradable, and low viscosity liquids in power transformers by the SGB-SMIT Group boosting towards sustainability targets. Collaborations with universities allowed digital tools to facilitate experiments, data collection, and the development of heuristic formulas for assessing the Lightning Impulse breakdown curves for oil gaps. This collaborative approach aims to create more efficient and sustainable transformers.

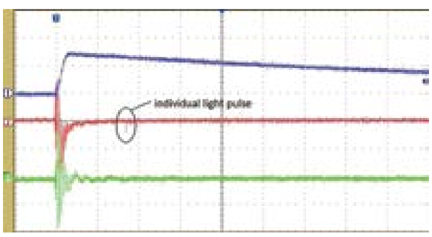


IVPD Measurement developed by the SGB-SMIT Group equipped with fiber optic sensors on the external surface of the transformer tank and real-time signal processing of PD.

Digitalization in electrical design

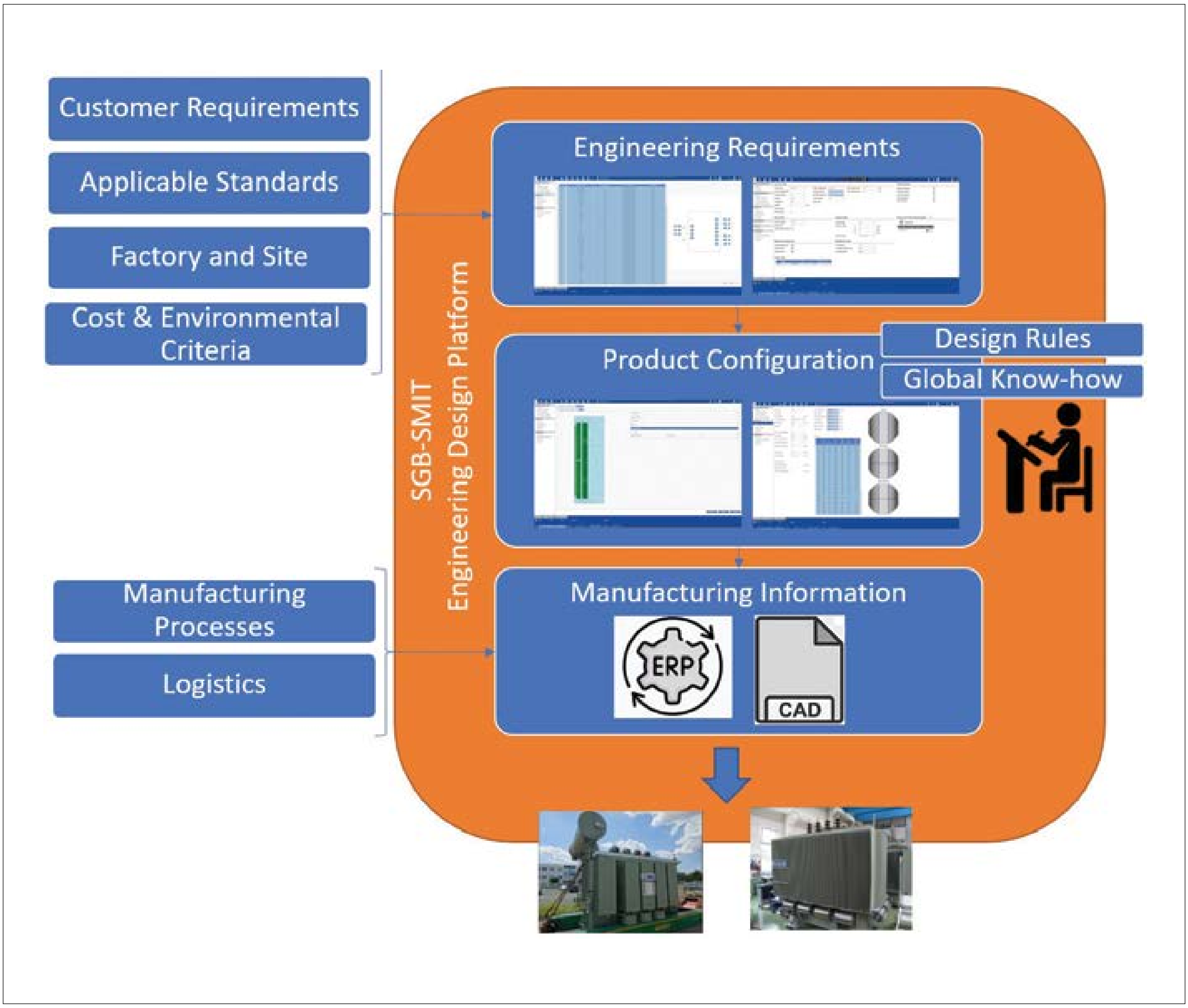
SGB-SMIT Group, a global player in the transformer market with 14 manufacturing plants, is leveraging digitalization in electrical design. The creation of a common design platform standardizes rules, practices, documentation, and materials across all factories. This unified approach increases efficiency, reduces waste, and enhances customer value.

The state-of-the-art Engineering Design Platform comprehends the entire process of transformer manufacturing in an optimized way. By creating a unified approach, SGB-SMIT Group aims to

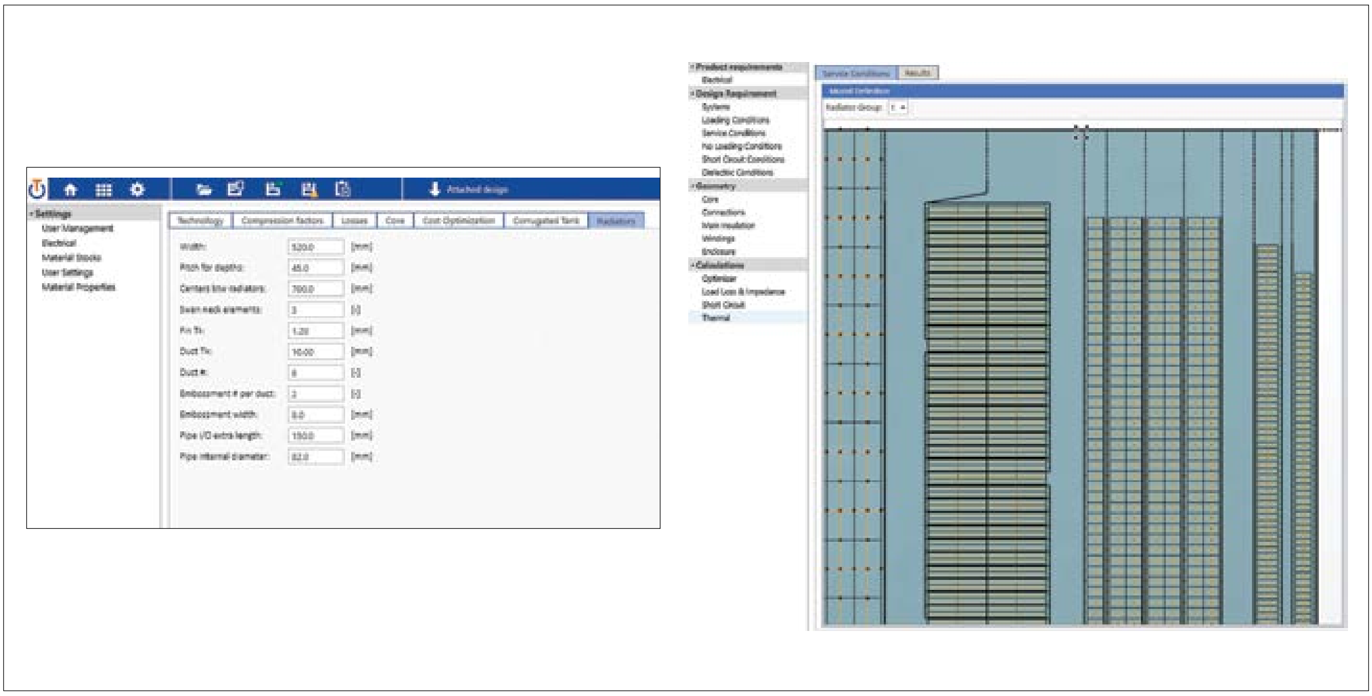


SGB-SMIT Group's laboratory testing of oil properties and assessment of Lightning Impulse Breakdown curves

SGB-SMIT Group's 80 MVA 115/21 kV power transformer with Gas-to-Liquids (GTL) insulating fluid



SGB-SMIT Group's Engineering Design Platform showcasing the synergy of transformer design



Creation of automatic/Semi-automatic optimized designs based on advanced computational techniques in the SGB-SMIT Group's digital design platform

Digitalization can also have a noteworthy application in the aspect of professional development, and SGB-SMIT Group deploys digital tools for training and nurturing new talents

increase efficiency, reduce waste, minimize processing time, and provide better value for the customers.

Towards sustainability goals

The digital design platform aligns with sustainability goals by reducing CO_2 emissions and optimizing material use. It includes advanced computation techniques for loss and short-circuit current calculations, ultimately leading to increased energy efficiency.

Professional development through digitalization

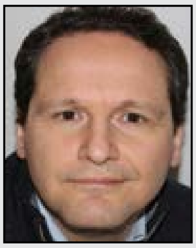
Digitalization extends beyond operations and product development; it can also have a noteworthy application in the aspect of professional development. SGB-SMIT Group deploys digital tools for training and nurturing new talents. These tools include physical and online project leadership training, on-the-job training, and collaboration with experts from esteemed universities on various research topics.

Conclusion

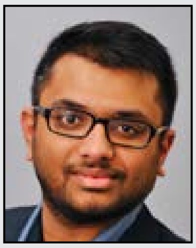
In conclusion, the power transformer industry is on a path towards sustainability, driven by digitalization, careful material selection, and advanced design optimization. As the industry moves towards its sustainability targets, digitalization remains a powerful ally, helping to reduce CO_2 emissions, enhance efficiency, and meet the evolving demands of the power transformer sector. The roadmap laid out by the SGB-SMIT Group serves as a testament to the industry's commitment to a more sustainable future.

Road map of the SGB-SMIT Group's Professional development through digital training

Authors



Marco Milone received the M. Sc. degree in Electrical Engineering from Politecnico di Milano, Italy and the MBA degree from SDA Bocconi School of Management, Milano, Italy in 1999 and 2004, respectively. Mr. Milone has been actively engaged in the transformer design and engineering since 2000. Since 2005 he has held several global management positions in transformer technology. He worked at the ABB Power transformer factories in Italy, Poland, and Germany. Since 2020, Mr. Milone has been with the SGB-SMIT Group, where he is currently the Group Technology Manager (CTO). His main areas of research interest are management of R&D teams, innovation management, simulation of high voltage and high current fields, electrical machine design, power transformer design and failure analysis, short circuit duties in power transformer, alternative fluids for HV applications. He is an active member of IEC TC 14 with contributions as MT member for IEC 60076-1, 60076-5, 61378-3.



Sudheer Mokkapaty received Bachelor of Technology degree in Electrical & Electronics Engineering from Jawaharlal Nehru Technological University, Hyderabad, India and Master of Science degree in Electrical Power Engineering from Brandenburg University of Technology, Cottbus, Germany in 2011 and 2015 respectively. Since 2014, Mr. Mokkapaty has been associated with the product development of electrical transformers initially as a student and later as a R&D Engineer in the business unit Distribution Transformers, SBG GmbH, Neumark. Since the beginning of 2023, he has been working with the SGB-SMIT Group as R&D Project Manager and currently as Group Innovation Manager. His main areas of interest are innovation, research and development management, FEM simulation of HV and LV applications, electrical steel technologies and product development in transformers. He has authored & co-authored multiple technical papers on transformers for different international technical conferences and fairs.

Transforming transformer testing

Key Strategies for the Industry in the Age of Energy Transition, Sustainability, and Digitalization

ABSTRACT

In an era characterized by energy transition, sustainability, and digitalization, the world is experiencing a profound transformation. For the power transformer industry, this new landscape presents both exciting opportunities and formidable challenges. As we navigate this changing terrain, it is essential to explore why testing solutions for the energy grid of tomorrow are crucial. At HAEFELY, we recognize our role in shaping the next generation and are committed to addressing this critical question. We perceive a paradigm shift in the world of testing.

KEYWORDS:

sustainability, energy transition, renewable energy, EcoDesign directive, digitalization, testing

In an era characterized by energy transition, sustainability, and digitalization, the world is experiencing a profound transformation

Electronic Power Supply 1500 kVA

TRANSFORMERS MAGAZINE'S
INDUSTRY NAVIGATOR

Presented at Sustainability and Digitalization 2023 conference in Dubrovnik, Croatia

Transforming traditional test systems into state-of-the-art digital solutions is no longer optional, it's a necessity to stay ahead of the impending wave of change.

Sustainability: A transformative force in the transformer industry

Sustainability has never been a more compelling imperative. One of the most significant shifts we are witnessing is the transition to renewable energy sources, particularly solar and wind power. This evolution is revolutionizing the transformer business. In the past, a 1 GW power generation system typically required two large power transformers. However, today, for a 1 GW wind power generation system, we need 200 small power transformers, and for solar power generation, the number escalates to 600 small power transformers. These transformers serve critical roles in an increasingly inaccessible and mission-critical environment. Consequently, they undergo more intensive and deeper testing than traditional standards demand. In summary, the industry must produce more transformers, subjected to more demanding tests, to meet the requirements of sustainable energy generation and distribution.

Transformer losses and EcoDesign Directive: A regulatory shift

The EcoDesign Directive in the European Union has significantly strengthened the regulations surrounding transformer losses, with a particular focus on no-load losses. This change stems from the intermittent on-and-off cycles of transformers in networks with wind and solar energy generation, a deviation from the traditional continuous electricity generation. The no-load loss of transformers now plays a pivotal role in reducing CO_2 emissions.

In light of these transformative forces, transformer test engineers face the challenge of reconciling speed and accuracy, often considered contradictory objectives. As these trends reshape the testing landscape, the need for testing solutions in the energy grid of the future becomes increasingly evident. So, what key strategies and approaches are required to thrive in the face of unprecedented change? The answer lies in embracing digitization.

Embracing digitization: The path forward

It is paramount for the industry to acknowledge the changing landscape and embrace digitization. Transforming traditional test systems into state-of-the-art digital solutions is no longer optional; it's a necessity to stay ahead of the impending wave of change. The impact extends to all players in the transformer market, from large corporations to family-owned businesses. Those who act swiftly will lead the charge.

At HAEFELY, we have observed this trend reflected in the increasing number of "new buyers" on our reference list for our Distribution Transformer Test System (DTTS).

Digitalization: Game-changing advancements in transformer testing

Digitalization is not just an upgrade; it's a revolution in transformer testing. Upgrading from traditional Motor – Generator hardware to state-of-the-art solutions, such as electronic power supply (EPS), brings a plethora of advantages:

Upgrading from traditional Motor – Generator hardware to state-of-the-art solutions, such as electronic power supply (EPS), brings a plethora of advantages

1. Compact hardware: EPS offers an optimized kW/kg and kW/m^3 ratio, generating no vibration. Its design allows for easy transportation and factory relocation.

2. Maintenance-free: Electronic power supply technology is virtually maintenance-free, with no moving parts apart from the cooling fan.

3. Ease of service: Standardized hardware and online monitoring make service efficient and spare parts readily available worldwide.

4. Safety: The EPS integrates advanced safety features, reacting intelligently to various situations, including voltage and current trip detection. It holds SIL3 certification, one of the highest safety levels in the industry.

5. Redundancy: EPS units can be used in parallel, providing increased power for testing. This flexibility allows for various test configurations, including parallel testing or testing larger transformers.

6. Decoupled power supply: The EPS provides decoupling from the mains voltage, frequency, distortion, and asymmetry, ensuring a clear separation between the test system and the workshop.

7. Compatibility with partial discharge measurement: Electronic power supply technology, coupled with filtering options, enables precise partial discharge measurements with minimal background noise.

8. Variable frequency: The ability to vary the frequency from 16⅔ to 200 Hz allows for versatile testing, including applied voltage tests, loss measurements at 50 Hz and 60 Hz, and induced voltage tests at any frequency.

9. Advanced control software: Real-time feedback loops ensure voltage symmetry and a reduced total harmonic distortion, enhancing accuracy.

10. Full working range: EPS technology is fully compatible with inductive and capacitive loads, simplifying testing.

Real-time feedback and transformative impact

One of the most significant advancements lies in the real-time feedback loop, connecting measurements taken on the transformer's bushing to the electronic power supply. This ingenious algorithm works wonders, minimizing total harmonic distortion (THD) to levels below 1% in the majority of cases. It doesn't stop there; this algorithm also addresses issues related to symmetry and has the remarkable ability to counterbalance unsymmetrical loads. In a real-world case study, the activation of this real-time algorithm led to a remarkable 3% reduction in no-load loss readings. The implications are truly astounding when one considers the feats that such sophisticated software can achieve on a multi-megawatt power supply. This innovation represents a game-changing leap in transformer testing technology, delivering precision and efficiency beyond what was previously imaginable.

One of the most significant advancements lies in the real-time feedback loop, connecting measurements taken on the transformer's bushing to the electronic power supply

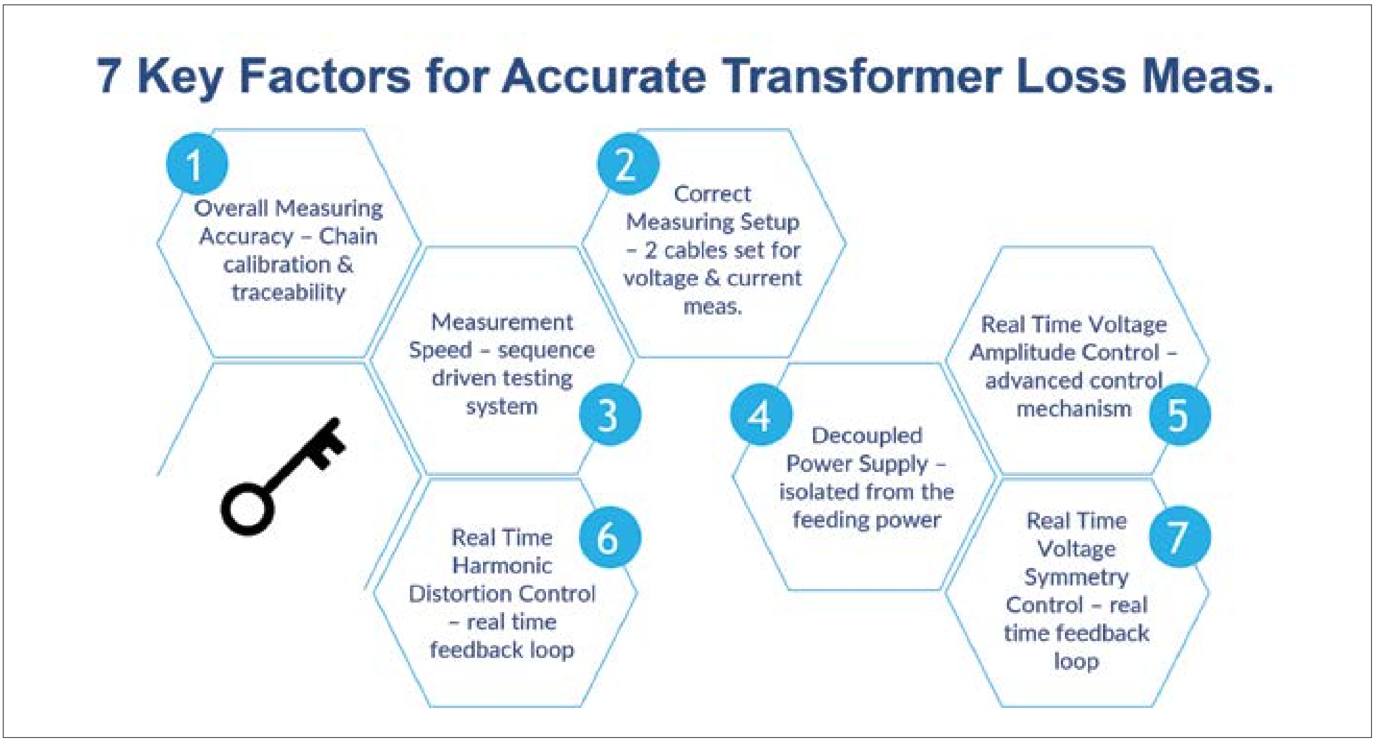
Modularity and flexibility: Meeting market demands

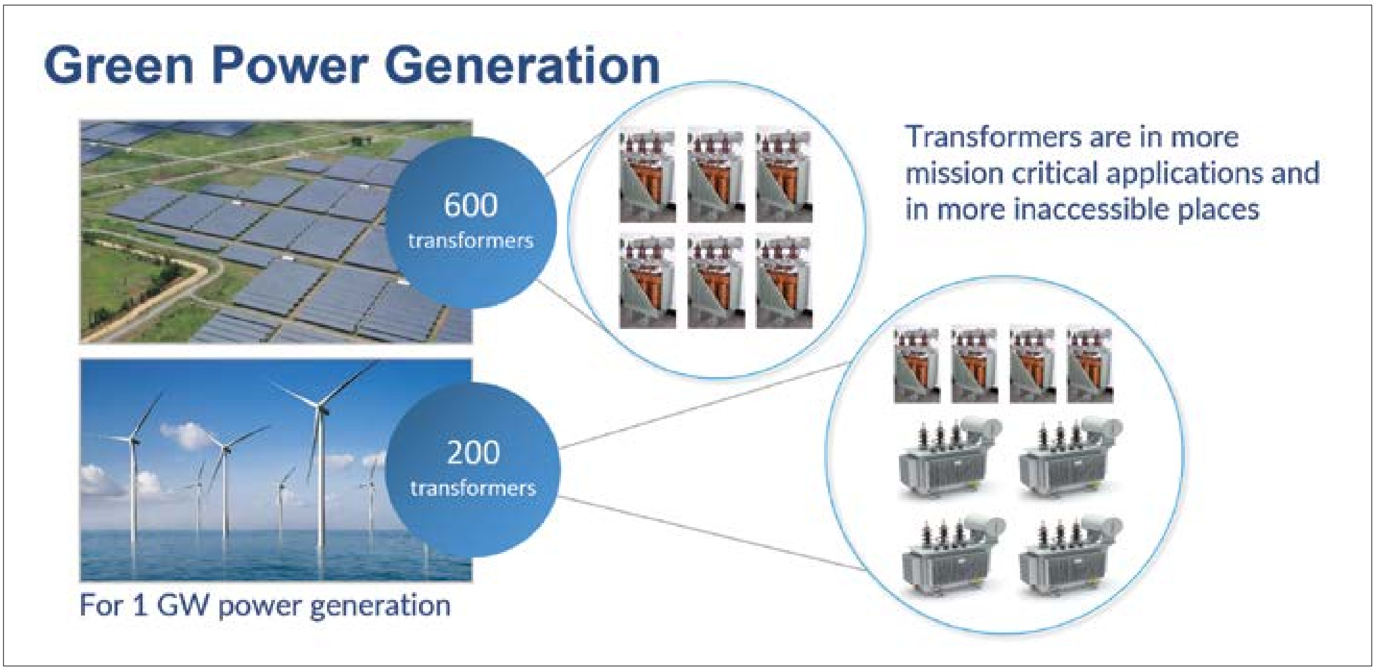
Amid the dynamic nature of the market, it's essential to adapt swiftly and remain open to future evolution. Timely delivery and flexibility are key considerations for any investment in today's transformer testing landscape. This state-of-the-art EPS presents a fully standardized and modular system. Each EPS unit, offering 540 kVA, can be conveniently stacked together to meet the power requirements for testing. This user-friendly approach offers numerous advantages. Systems can be upgraded on-site to accommodate increased power demands, all while maintaining standardized components, which facilitates faster delivery and streamlined spare part management. In the case of a large system, if one EPS unit encounters issues, the remaining units ensure the system's continuous operation. Additionally, it's possible to run two medium-sized test systems in parallel to test two medium-size transformers and combine their power for testing large power transformers. This adaptability positions EPS as a powerful hardware for navigating the evolving testing landscape.

Global view with safety features

The EPS comes equipped with software that not only monitors but also drives the entire test laboratory, even including third-party components. It continuously senses the state of every switch, interlock door, and takes measurements from the EPS, capacitive compensation bank, and

In the world of transformer testing, where we confront the challenge of balancing speed and precision, we're equipped with a robust toolbox that significantly simplifies the life of a test engineer





step-up transformer. This top-tier software incorporates advanced features such as voltage and current trip detection and flash detection, significantly enhancing safety throughout the system and the entire factory. In the event of a malfunction or an unforeseen situation, the system immediately switches off, entering a secure state. Instances of capacitive compensation banks failing due to operator errors or over-stress are not uncommon. However, with this software, such catastrophic scenarios can be predicted and avoided, earning it a SIL 3 safety certificate.

These advancements make a compelling case for EPS technology and its transformative potential in transformer testing.

Balancing speed and precision in transformer testing

In the world of transformer testing, where we confront the challenge of balancing speed and precision, we're equipped with a robust toolbox that significantly simplifies the life of a test engineer. This toolbox includes transformative elements such as a transformer database, automated hardware configuration, streamlined test sequence setup, automated measurements, and standardized result calculations based on industry standards and pass-or-fail criteria. It also seamlessly generates test reports, accelerating the testing process. For instance, with our DTTS, cycle times as short as 7 minutes per transformer are attainable, depending on the system configuration – a remarkable feat compared to the bygone era when measurements were meticulously handwritten in notebooks.

The new era is here, and for the industry to prosper in the face of unparalleled transformation, it must enthusiastically adopt these innovations

These digital tools not only enable us to expedite the testing process without compromising measurement accuracy but also play a pivotal role in upholding the integrity of our Quality Management procedures. Each step in the process is meticulously defined, ensuring that every transformer undergoes testing in a standardized manner, regardless of the operator. Additionally, traceability is effortlessly maintained, as the system offers a fully calibrated setup and a comprehensive test report database. This powerful combination of speed and precision is the driving force behind our transformation in the testing landscape, guaranteeing consistency and excellence in every test.

The new era is here, and for the industry to prosper in the face of unparalleled transformation, it must enthusiastically adopt these innovations.

Author

Frédéric Dollinger, Area Sales & Marketing Manager at HAEFELY, shared his groundbreaking insights on "Transforming Transformer Testing" at the Transformers Magazine Sustainability and Digitalization 2023 conference in Dubrovnik, Croatia. With over a decade of experience in the transformer industry, he is passionate about pioneering cutting-edge solutions that revolutionize the efficiency and accuracy of transformer testing. A frequent speaker at industry events, he actively travels the globe, sharing his expertise with customers and collaborating on projects.


WiPE
Women in Power Engineering

The energy of craftsmanship – In the era of digitalization: PTTX Putian Group success story

ABSTRACT

PTTX Putian Group is pioneering a green energy transformation in the electric power sector. With a fully integrated mill and a unique example of vertical integration, they are expanding their core manufacturing capabilities to meet the growing demand. This article showcases how PTTX Group is driving advancements in electrical steel material technology to create a greener and more low-carbon future.

KEYWORDS:

sustainability, digitalization, digital technology, electrical steel, smart factory, iron cores

The evolution of the transformer industry is marked by two key themes: sustainability and digitalization

TRANSFORMERS MAGAZINE'S
INDUSTRY NAVIGATOR

Presented at Sustainability and Digitalization 2023 conference in Dubrovnik, Croatia

PTTX Group specializes in high-end electrical steel materials, transmission and distribution electrical equipment, and integrated smart factory planning

The evolution of the transformer industry is marked by two key themes: sustainability and digitalization.

In recent years, both pre- and post-pandemic, the whole energy sector has experienced a constant demand for the improvement of transformer performance and the industry itself, achieving high levels of sustainability as well as device performance, both of which can be achieved with a boost in the digitalization of companies.

As a beacon of innovation, PTTX Putian Group stands at the forefront of these transformations. For over two decades, the Group has been dedicated to the electric energy sector. PTTX Group specializes in high-end electrical steel materials, transmission and distribution electrical equipment, and integrated smart factory planning. It consistently provides green, low-carbon products and comprehensive solutions for the entire industry chain through innovative technology.

As an indispensable and hidden component of electrical power networks, iron cores have a wide range of applications, including in transformers, electronic circuits, motors, power supplies, and more. All these appliances, which contain cores, support vital industries such as aviation, railways, high voltage transmission and distribution, data centres, and new energy sources such as windmills and photovoltaic farms.

PTTX Group boasts an industry-leading intelligent manufacturing base for silicon steel and iron cores. Leveraging our proprietary digital "brain," it established a fully interconnected, smart-controlled, and safe industrial internet system, encompassing marketing, research and development, production, intelligent logistics, customer service, and business management, creating a seamless end-to-end closed-loop. Empowered by technology, PTTX Smart Factories excel in core metrics such as product quality control, production efficiency, energy conservation, and environmental protection.

Innovation is the key to sailing towards the future: PTTX group places great importance on technological innovation and talent development. We have established strategic partnerships with leading domestic research institutions and universities, which provide the PTTX group a source of young, very highly technically skilled people who joined our team.

PTTX invested significantly in the creation of a research and development centre, where our technical experts are focusing on key areas like fundamental materials and green electrical applications. Located in Anhui Province, PTTX's own "Xinpu" mill spans a million cubic meters, boasts 18 kilns, and produces 300,000 tons of grain-oriented

electrical steel (GOES) for transformer manufacturers. The capacity is further set to increase from January 2024.

PTTX Group is also expanding its core manufacturing, building a new plant for cores, boosting the production by another 100,000 tons. The "Xinpu" mill is fully integrated with PTTX plants manufacturing cores, a unique example of vertical integration in the energy world.

PTTX Group is dedicated to expanding its domestic and international presence from a global perspective, with products and services already providing comprehensive coverage in the domestic market. Simultaneously, PTTX Group offers high-quality silicon steel and iron core solutions to hundreds of transformer manufacturing companies in over 50 countries and regions around the world, thus contributing to bringing electric power to every corner of the globe.

PTTX Group will continue to play a crucial role in the green and low-carbon transformation of the electric power industry through advancements in electrical steel material technology.

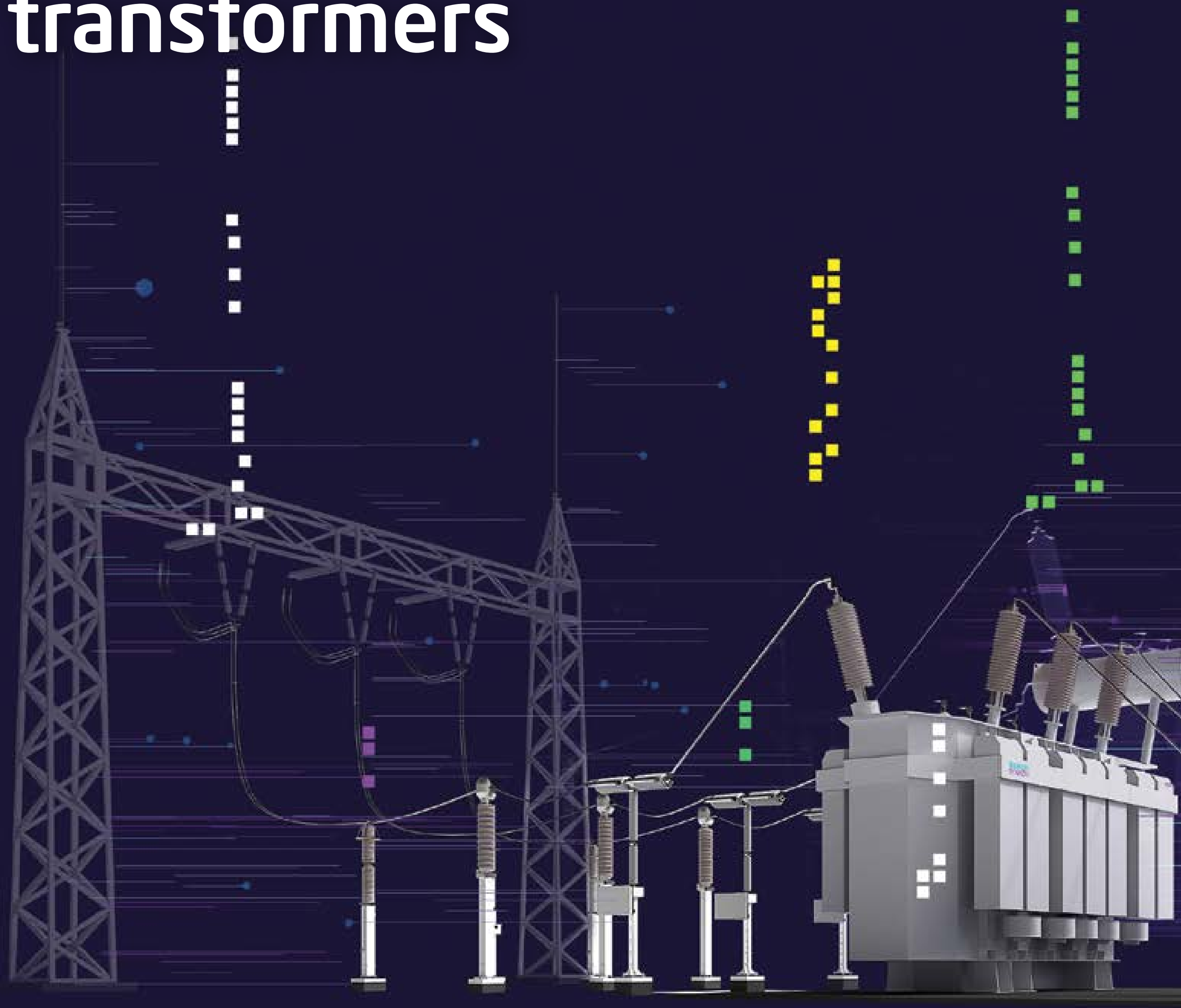
PTTX Group offers high-quality silicon steel and iron core solutions to hundreds of transformer manufacturing companies in over 50 countries and regions around the world

PTTX Group drives the development of new power systems, making life even better. Gathering the vision of the era, PTTX Group innovates the silicon steel branch. The "core" of PTTX Group listens to the heartbeat of the world.

Acknowledgments

The author would like to thank the PTTX Marketing team for their contributions to the creation of this article.

Sensformer: Powering the future with digitalized transformers



Amit SHEREKAR, Manan PANDYA

The traditional transformer, which has been a cornerstone of the power grid for over a century, is being transformed into a digitalized version that can provide operators with real-time data on its operation and health

ABSTRACT

Transformer digitalization is a critical aspect of the development of a smart grid. Siemens Energy has developed a digital transformer solution called Sensformer, which integrates various sensors, communication interfaces, and data analytics capabilities into the transformer to enable advanced monitoring, diagnostics, and prediction capabilities. This article presents an overview of the Sensformer and its key features. It describes the installation and commissioning process of the Sensformer and the benefits of the technology in terms of improved reliability, efficiency, and safety of power systems. A case study is presented to demonstrate the features of the Sensformer in real-world applications, such as detecting hot spots in transformer windings, predicting transformer ageing, performing DGA and optimizing transformer loading based on real-time condition monitoring. The results show that the Sensformer can significantly enhance the performance and value of transformers and provide a reliable and cost-effective solution for grid digitalization..

KEYWORDS:

Sensformer; digital twin; IoT-cloud; relative aging; digitalization.

Sensformer is a digital product introduced by Siemens Energy in 2018 which provides real-time information about the performance and health status of transformers

Introduction

The rapid development of digitalization technologies has opened new possibilities for the power industry to optimize their operations and improve the efficiency of their power grids. The traditional transformer, which has been a cornerstone of the power grid for over a century, is being transformed into a digitalized version that can provide operators with real-time data on its operation and health. Transformers are a critical component of electrical power systems, and their performance directly impacts the reliability and efficiency of electricity transmission and distribution. Traditional conditioning monitoring systems have been used for years to evaluate the health and performance of transformers. However, with recent advances in digitalization, the development of digitally enabled transformers has become essential to address current and future challenges facing the power industry. These challenges include improving performance, health and safety, reducing costs and risks, and meeting environmental goals. Digitalization offers advantages such as reduced downtime, increased flexibility, cost savings, and improved environmental protection. This paper will focus on the digitalization of transformers, exploring the features and benefits of digital transformers, such as active overload management, temperature monitoring, and aging prediction. Overall, this paper aims to demonstrate how the digitalization of transformers can improve the efficiency, reliability, and sustainability of the power grid, providing a foundation for a fully digital grid.

Sensformer

Sensformer is a digital product introduced by Siemens Energy in 2018 which provides real-time information about the performance and health status of transformers. The product consists of an IoT gateway, cloud, and digital twin modelling of the transformer, which enables remote monitoring and management of the transformer's health status. The Sensformer solution is available for the complete power transformer portfolio, including Auto-, Net-Transformer, phase shifters, reactors, and HVDC transformers. One of the key features of Sensformer is its ability to provide real-time data on the transformer's performance and health status through a web-based user interface and mobile apps. This data can help utilities and other users optimize the performance of their transformer assets, identify potential problems before they become critical, and reduce downtime and maintenance costs. Another important feature of Sensformer is its digital twin modelling capability. A digital twin is a virtual replica of a physical asset. By creating a digital twin of the transformer, users can simulate and analyze its behaviour under various conditions in order to optimize its performance, identify potential problems, and develop predictive maintenance strategies. Some of the benefits of using Sensformer include improved reliability and availability of transformer assets, reduced maintenance costs, and increased efficiency in transformer operations. Additionally, Sensformer can help utilities make data-driven decisions about maintenance, repairs, and replacement. Siemens Energy extends the Sensformer solution to encompass non-Siemens transformers as well. This enables users to upgrade their existing transformer assets with the digital monitoring and modelling capabili-

Figure 1. IoT Box

ties of Sensformer, providing them with the same benefits as new installations.

Sensformer consists of the IoT gateway box shown in Figure 1. Real-time data communication is facilitated by its interaction with the transformer and the cloud. Figure 2 shows data flow from the transformer to the cloud via the IoT device and from the cloud to a mobile device/web UI. The IoT gateway that is installed into the control cabinet of the transformer measures the physical signals coming from the transformer. These signals include load, winding temperature, top oil temperature, cooler temperature, ambient temperature and the measurement of gases. The IoT device has the functionality of connecting the cloud through a GSM/LAN network. Therefore, all values obtained from the transformer are sent to the cloud platform for data analysis. Along with Sensformer, Siemens Energy has a broad range of Sensproducts family intended for grid digitalization.

The Sensformer solution complies with the industry-leading cybersecurity requirements and uses state-of-the-art security and encryption technologies, including ISO/IEC 27001. End-to-end encryption is employed for data transmission to cloud storage, with each Sensformer having a unique ID used for encryption. HTTPS with 256-bit TSL encryption is used for transmission. To ensure strict separation and security of data from different customers in the cloud, Sensformer adheres to the best-in-class data handling and management guidelines. After the digital twin model of the transformer is built on the cloud platform, detailed information about the transformer can be accessed via a mobile device/web UI. Real-time temperature monitoring of oil and winding is displayed on the digital screen, with the digital twin providing real-time loss of life calculation and active overload prediction, as well as warning users when the temperature exceeds defined limits.

Sensformer features

1) Mixed reality view – The operator can interact with the web-based UI to verify physical signal values coming directly from the transformer. The digital twin of the transformer provides additional calculated signals called 'virtual sensors,' which can be treated as real sensors. These virtual sensors save money and time while enabling more insights into the transformer's inner life and condition. This includes extended temperature information with advanced 3D visualization, selectable signals of different values and components, as well as a virtual sensor notifier. This notifier can be parametrized to inform the operator about the status of the transformer anywhere and anytime.

2) Active overload prediction – Active overload prediction is based on real-time thermal modelling of the transformer, obtained using the historical operational data of the transformer. With the help of the digital twin, the real-time thermal image of the transformer can be simulated at any time during operation and stored in order to have a sound base for load prediction. Different load scenarios can be simulated before loading the transformer, so the level and duration of the overloading that the transformer can withstand is known to the operator at any time. The operating parameters are adjustable according to the operator's requirements,

The Sensformer solution complies with the industry-leading cybersecurity requirements and uses state-of-the-art security and encryption technologies, including ISO/IEC 27001

Some of the main features of Sensformer include Mixed reality view, Active overload prediction, Load Simulation, Lifetime prediction and DGA and Multigas Sensor Integration

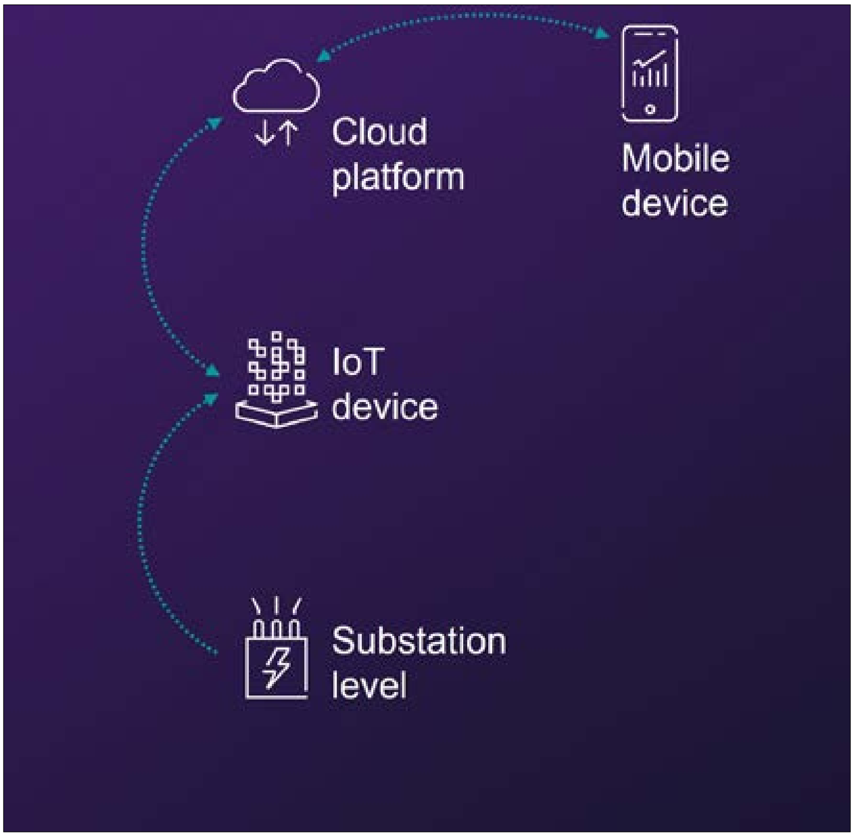


Figure 2. Sensformer data flow

> A digital twin is a computer-based model that replicates a connected transformer using design data and operational information

and overload prediction is possible up to 3/24 hours into the future. Thus, transmission capacity can be increased based on a very accurate forecast. At the same time, operating flexibility is maximized to match the operator's business needs.

3) Load Simulation – With a calibrated digital twin model, it is possible to evaluate the load cycle simulation for the following 24 hours based on the load profile and ambient temperature. This provides advanced information regarding the operating condition of the transformer, including the top oil temperature and winding hot spot. Different load scenarios, along with ambient temperature, can be simulated on the cloud platform in a short time.

4) Lifetime prediction – The Sensformer application allows operators to monitor the aging of insulation paper in transformers by analyzing load and other operational parameters of the transformer. By retrospectively evaluating the transformer's operating mode, it is possible to calculate the actual lifetime losses over a predefined period and generate both absolute and relative lifetime loss forecasts. In accordance with IEC loading guidelines, the system also supports continuous lifetime evaluation over a longer period. To accurately predict load, flexible parameterization for aging is necessary. By predicting the transformer's lifetime based on insulation aging estimation, operators can assess the age profile of their transformers at any given time, enabling them to plan for future capital expenditures with greater accuracy.

5) DGA and Multigas Sensor Integration – The integration of H2 guard and Multigas (Multisense5 and Multisense9) sensors with the Sensformer application is possible. This enables a detailed analysis of the concentration of gases present in transformer oil, along with trend analysis. If the specified limits for any particular gas are exceeded, the operator is alerted. Online DGA monitoring allows for continuous tracking of transformer health and provides in-depth information about the condition of transformer oil. The system can also detect faults using techniques such as Rogers Ratio and Duval Triangle based on standards. Furthermore, with the requisite sensor inputs from DGA, relative aging calculations are more precise due to the moisture modelling phenomena.

Sensformer benefits

1. Real-time information of operational parameters of the transformer is available anywhere and anytime.
2. Early warnings and push notifications on mobile devices to alert operators about critical situations (e.g., oil loss, excessive temperature, etc.)
3. Performance optimization is achievable by monitoring the different parameters of the transformer.
4. Sensformer data can be used to cut maintenance costs by reducing man-hours and preventing unscheduled outages.
5. Customers have 24/7 access to Sensformer applications and can use the information provided to cut operating expenses.
6. Historical data download is possible, and it can be used to understand transformer behaviour in detail.
7. Active overload prediction and insulation aging support the lifetime planning of transformers, which is beneficial for long-term grid modernization.

Digital twin

A digital twin is a computer-based model that replicates a connected transformer using design data and operational information. This virtual replica can be created

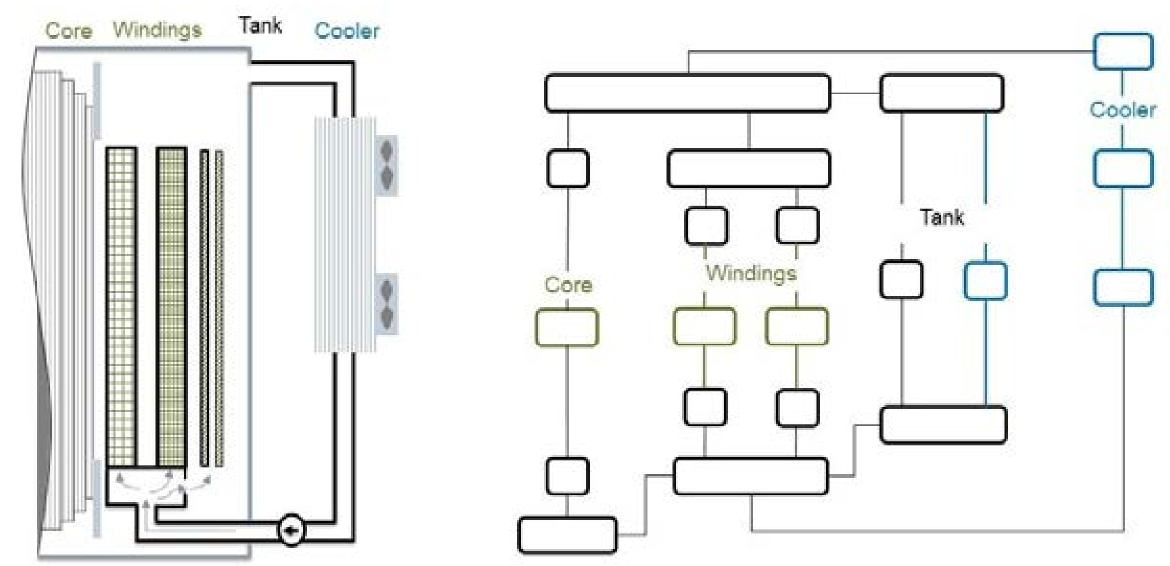


Figure 3. Heat sources of a transformer to build a thermo-hydraulic model, including the oil flow

in real-time, using current data input, or in advance, based on simulated operating scenarios. The digital twin provides a detailed and accurate representation of the transformer, allowing engineers and operators to monitor and optimize its performance, predict potential issues, and simulate future operating conditions. In cases where detailed design data is not available, modelling is done based on IEC/IEEE standards. By using a digital twin, utilities or operators can improve asset reliability, reduce downtime, and enhance overall operational efficiency.

The thermo-hydraulic model presented in Figure 3 is a powerful tool for computing the temperature behaviour of the transformer. It takes a variety of factors into account, including the transformer ratio and tap position, and distinguishes between different types of losses, such as ohmic and eddy losses, which have distinct temperature dependencies. One unique feature of this model is its ability to incorporate real material characteristics, such as the masses and heat capacities of conductive and insulating materials, to accurately predict the dynamic temperature behaviour that occurs during operation. In addition, the model accounts for the hydraulic resistances of various transformer components such as the core, windings, and radiators. It calculates oil flow based on buoyancy forces and, optionally, additional pump pressures if pumps are present. With this level of detail and accuracy, the thermo-hydraulic model enables engineers to model the exact digital twin of the connected transformer.

Consequently, and contrary to more simplified models, the Siemens Energy digital twin does not rely on fixed thermal time constants. Instead, it can account for the relevant dynamic heat transfer mechanisms in the transformer. Using this thermo-hydraulic approach, the heat transfer equations take into account the relevant physical quantities such as oil temperature, oil flow, losses, etc. Considering the oil flow distribution and heat transfer mechanisms results in a thermal transformer model covering different cooling modes and the transient behaviour between these modes, like ODAF to ONAF or ONAN. The result is a precise temperature calculation. Moreover, due to the multi-mass approach linked to the oil flow, it is possible to integrate the model with other important physical transformer models, such as those for moisture calculation.

By inputting various operational data for the following 24 hours, customers can simulate a load cycle and gain a deeper understanding of their transformer's future behaviour

Currently, the digital twin model in Sensformer can be used for three scenarios. Firstly, it can simulate load and ambient temperature cycles for a period of 24 hours in the future. Secondly, the model can determine permissible overload with specified boundary conditions. This feature enables the transformer to be operated more efficiently and optimally without the risk of damage or failure. Finally, the digital twin model can automatically calculate the relative aging of the transformer, which is crucial in predicting its remaining lifespan and scheduling maintenance activities.

The Sensformer Advanced offers customers valuable insights into the condition of their transformers. By inputting various operational data for the following 24 hours, customers can simulate a load cycle and gain a deeper understanding of their transformer's future behaviour. The thermo-hydraulic model then predicts temperature behaviour for the transformer, such as top oil temperature and winding hotspots over 24 hours, starting with the current thermal condition of the transformer. Customers can also determine the maximum permissible overload capacity for the transformer over the following 3 hours, considering different boundary conditions such as temperature limits and aging values. Additionally, the Sensformer Advanced can automatically calculate the relative insulation aging of a transformer based on the IEC loading guide formulas. It also considers the moisture present in the oil for loss-of-life calculation. This loss of insulation life is calculated based on data from the previous 24 hours, the previous 30 days, and since the Sensformer application was commissioned. This provides customers with a real-time assessment of the transformer's lifetime and the ability to compare the thermal load of multiple transformers.

Customized design modelling

Each transformer has its unique design, which includes factors such as oil-natural or oil-directed cooling, the number of windings, coolers, fans, and other specifications. To accurately predict the transformer's behaviour, a digital twin model is created, which is tailored to the transformer's specific design. The digital twin model is parameterized with design information such as oil volume, heat capacities, insulation thicknesses, ohmic resistances, hydraulic resistances, dimensions, materials, thermal data, fan and pump characteristics, and many other factors. By utilizing real-world data, the thermohydraulic calculation of the digital twin model can predict the transformer's overload capacity, aging, and service requirements with a high degree of accuracy. This level of accuracy is crucial for ensuring the safe and reliable operation of transformers in the power system.

The main difference between simplified standard thermal models and the Siemens Energy digital twin is the multi-mass approach. Simple models often consider only the thermal behaviour of a single winding for a specific tap position and specific cooling mode. It is only possible to simulate the hotspot temperature for load and ambient changes for this

Each transformer has its unique design, and to accurately predict the transformer's behaviour, a digital twin model is created, which is tailored to the transformer's specific design

By accurately predicting temperature behaviour, the digital twin can provide valuable information for monitoring and optimizing the transformer's performance, leading to improved reliability and efficiency

winding. However, this is clearly less accurate and not sufficient in terms of real thermal stress within a transformer, as the position of the highest temperature can vary from one winding to another when a transformer is operated at a different tap position.

In contrast, the Siemens Energy digital twin covers all windings and the possible cooling modes of the transformer. Depending on the tap position, the loss distribution occurring in the windings is calculated, and consequently, the hotspot in the transformer can be continuously calculated. The Siemens Energy digital twin is based on a multi-mass model, which also includes the oil flow. Only these models will really constitute a complete digital twin of a transformer, which will allow a very deep insight into the transformer.

Temperature behaviour is a crucial aspect of digital twin technology, as it provides valuable insights into the accuracy of the calculation model used. Figure 4 illustrates a comparison of measured and calculated values of top oil temperature over a certain period of time for an oil-natural-cooled medium power transformer. The results show that the digital twin provides the most accurate correlation between the measured and calculated temperature values. In contrast, the conventional IEC standard model produces higher deviations, leading to less accurate estimated conditions. This highlights the importance of using a comprehensive multi-mass approach such as the one used in the Siemens Energy digital twin, which considers all windings and possible cooling modes. By accurately predicting temperature behaviour, the digital twin can provide valuable information for monitoring and optimizing the transformer's performance, leading to improved reliability and efficiency.

Successful installation of Sensformer Advanced in India

As part of our initiative to drive digitalization activities for transformers in India, we have successfully commissioned the Sensformer Advanced solution on a transformer within our premises. This retrofit solution is installed on an existing transformer with a capacity of 25 MVA, 220/22 kV. This pilot project has demonstrated the capabilities of this technology and its potential benefits, providing us with first-hand experience in refining our processes and developing best practices for our customers.

Figure 5 shows the actual site picture of the transformer and the commissioning of Sensformer. All the sensors on the transformer are connected to the IoT box and transmit the data of various operational parameters in real-time to the cloud platform for analysis. Figure 6 shows real-time data of the transformer on the platform and data analytics for decision-making. Figure 6 (a) shows the fleet management and status of all the transformers in the fleet and their running condition. Figure 6 (b) shows the loading of the transformer and critical operating parameters. Figure 6 (c) shows the real-time data for each of the sensors which are connected to the IoT box. Figure 6 (d) shows the transformer's behaviour in real-time and the virtual sensor calculation for detailed insights into the transformer behaviour. Multisense 9 is integrated with the Sensformer application to check the condition

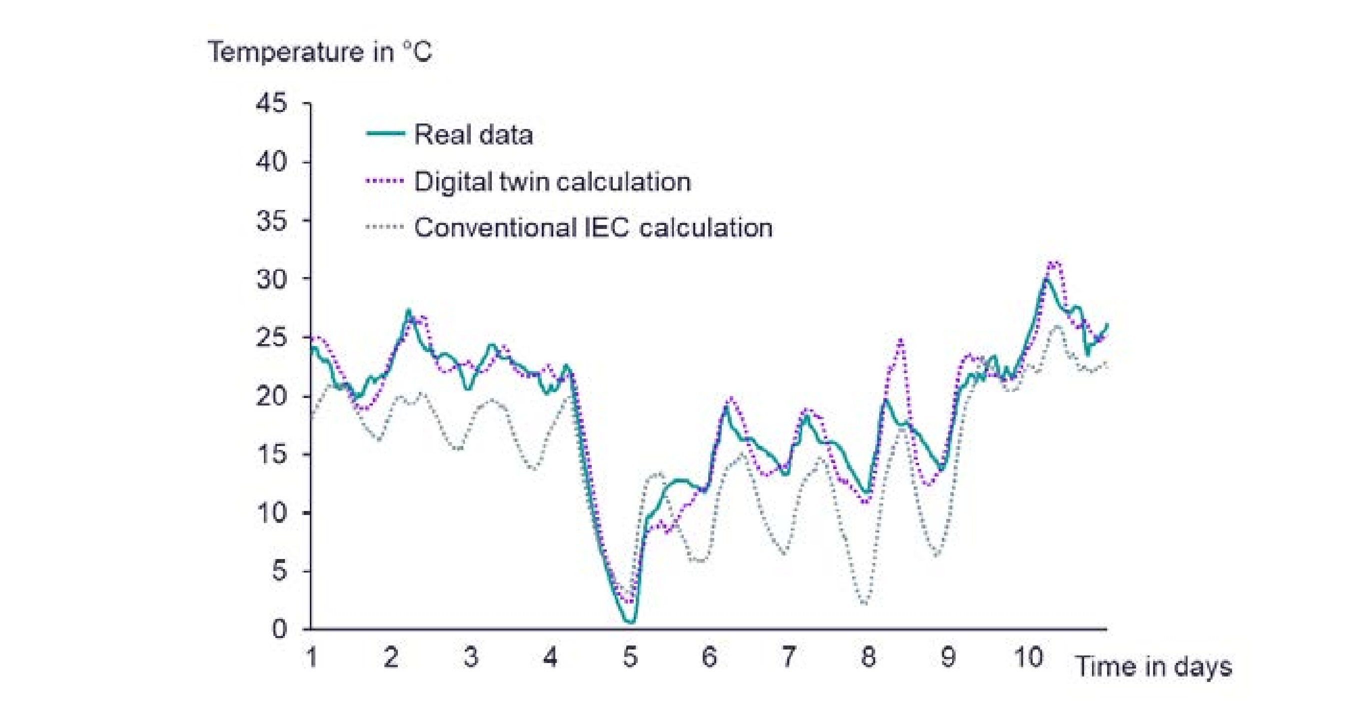


Figure 4. Comparison of different calculation methods for transformer top oil temperature

of the transformer oil, the concentration of different gases and their trend analysis. The platform employs advanced analytics and machine learning algorithms to process the data, providing insights into the transformer's health and condition. This enables predictive maintenance, reducing downtime and repair costs and ultimately extending the transformer's lifespan. Online monitoring eliminates the need for physical inspections and minimizes the risk of human error.

The successful implementation of this pilot project highlights Siemens' commitment to digital transformation and paves the way for the adoption of digitalization in the power sector in India. This installation is used as a demo platform for our potential global customers to showcase the capabilities and features of the Sensformer application. This solution is an IoT-based digital tool that allows for transformer health monitoring and transformer fleet management, optimizing transformer utilization in real-time. With this solution, Siemens aims to drive innovation in the power sector, delivering sustainable and reliable energy solutions to its customers.

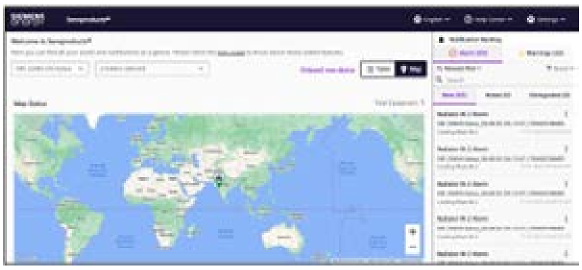
Conclusion

The Sensformer system offered by Siemens Energy is a digital solution for transformer online monitoring to access critical information about the status and performance of transformers. It provides customers with real-time access to critical data on their transformers, including loadings, aging forecasts, temperatures, and dissolved gas concentrations. This system enables early fault detection with automated alarms and provides maximum transparency regarding the actual condition of the transformer. The digital twin intelligence also allows for virtual simulation of the transformers' operating parameters under different load conditions.

By providing real-time data on transformer performance, the Sensformer system enables customers to take proactive measures to minimize risks, optimize transformer operation, reduce OPEX costs, and enhance transformer lifetime planning, thus improving the reliability and efficiency of power grids.

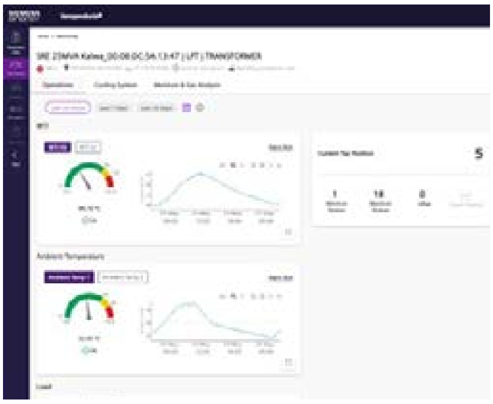
As part of our initiative to drive digitalization activities for transformers in India, we have successfully commissioned the Sensformer Advanced solution on a transformer within our premises

Figure 5. Site picture during Sensformer commissioning



a) Fleet Management

b) Loading of the transformer



c) Operational parameters of the transformers

d) Real-time data analysis

Figure 6. Sensformer Advance Platform showing Live Parameters

The Sensformer system offered by Siemens Energy is a digital solution for transformer online monitoring to access critical information about the status and performance of transformers

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Authors

Amit Sherekar received his master's degree in heat power engineering in 2012. He has 11 years of experience in thermal and cooling simulations. He is currently working as a manager at Siemens Limited, India. He has developed a thermal-hydraulic network model for predicting oil flow and winding temperature in transformers. He has experience with computational fluid dynamics (CFD) modelling for predicting oil flow and temperature in various cooling configurations of power transformers.

Manan Pandya has 20 years of diverse experience in large power transformer manufacturing, design, R&D and Innovation at ABB and Siemens. He has expertise in transformer mechanical design, electrostatics, and electromagnetics field simulation. He was awarded the "Innovator of the Year 2017" award at Siemens India and holds 3 international patent applications. He established the Transformer Competence Centre at Siemens India for supporting engineering and R&D of Global Siemens transformer sites. Currently, he is working at Siemens Energy Transformers, Nuremberg, Germany, as an operational excellence manager.

PEER REVIEWED


Transformers
ACADEMY

Thermal failure in a clamping bolt of a shunt reactor

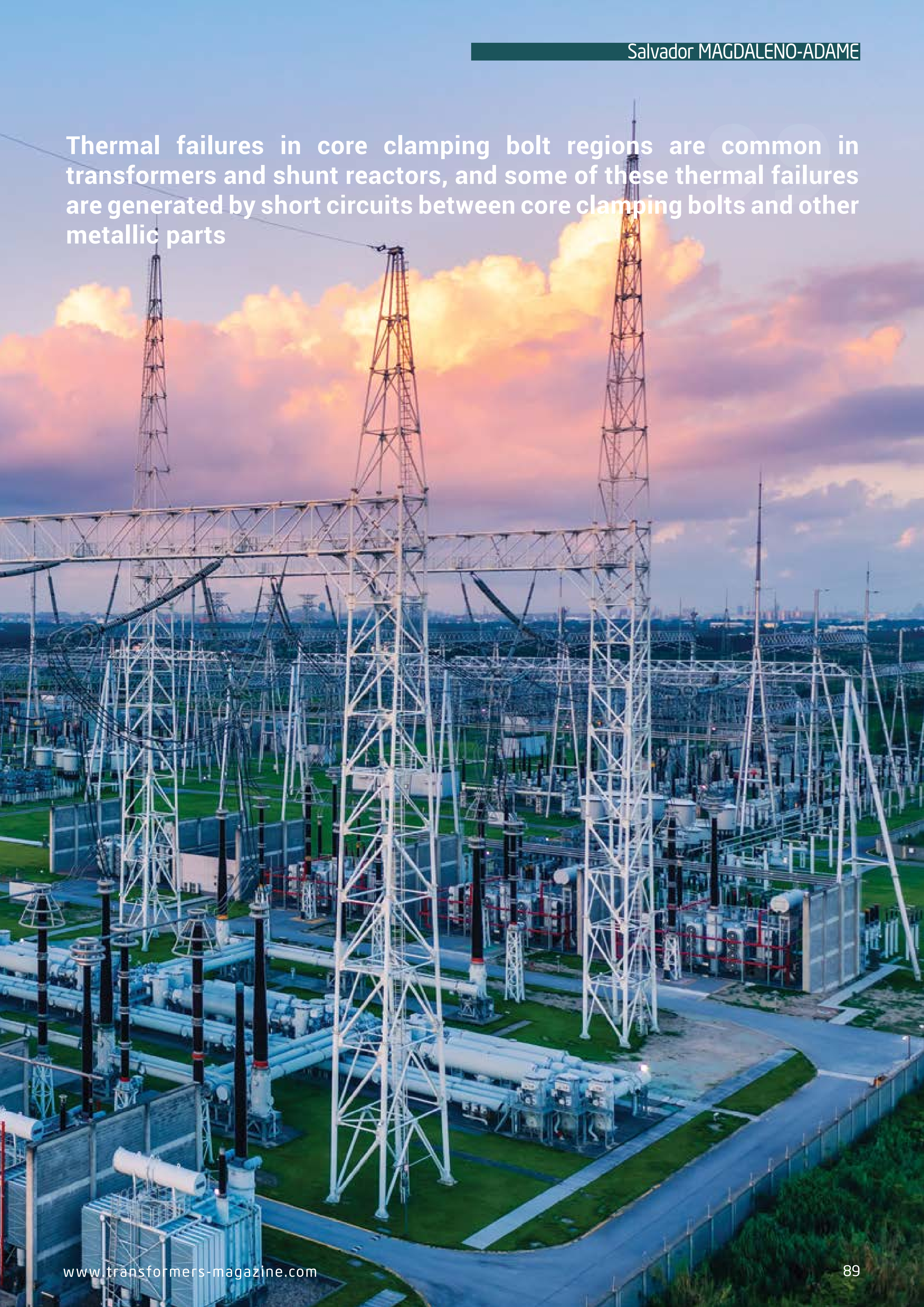
ABSTRACT

This article presents the detection and analysis of a thermal failure produced in a core clamping bolt of a 5 MVAr gapped three-phase shunt reactor. Gases were detected in this shunt reactor during its operation at a substation in Mexico. Using dissolved gas analysis (DGA) and Duval's triangle method, temperatures up to 700°C were estimated in the shunt reactor. Overheating evidence was detected in one of the core clamping bolts during an internal inspection of the shunt reactor. The author and the reactor manufacturer believe that the insulation of the clamping bolt was damaged by the loosening of the bolts produced by the vibration of the shunt reactor in conjunction with a possible low torque applied to the bolts. A short circuit between the bolt and the clamping frame was produced, generating the circulation of eddy currents in the bolt producing high temperatures and gasifying the insulating oil in the shunt reactor. Three-dimensional (3-D) finite element (FE) simulations were performed to verify the cause of the overheating issue in the clamping bolt of the shunt reactor, simulating the short circuit between the clamping bolt and the core frame. From the simulation results, the author determined that a short circuit between the bolt and the core frame generated the gases and the high temperatures in the shunt reactor. Finally, the manufacturer of the shunt reactor decided to reinforce the insulation of the clamping bolts using fiberglass to avoid future possible short circuit failures.

KEYWORDS:

shunt reactor; short circuit failure; finite element (FE) simulation, dissolved gas analysis (DGA), core clamping bolt, Duval's triangle method

Salvador MAGDALENO-ADAME



Thermal failures in core clamping bolt regions are common in transformers and shunt reactors, and some of these thermal failures are generated by short circuits between core clamping bolts and other metallic parts

The presence of gases was monitored and detected in a 5 MVAr three-phase shunt reactor during its normal operation condition

Introduction

Thermal failures in core clamping bolt regions are common in transformers and shunt reactors [1]–[3]. Some of these thermal failures are generated by short circuits between core clamping bolts and other metallic and magnetic parts, producing the circulation of high currents in these bolts [4]–[7]. These currents can develop high temperatures in the bolts and the near-clamping frame regions. In power transformers and shunt reactors that are immersed in insulating oil, these high temperatures break down the oil and generate gases, which leads to a failure of these apparatus during their operation in the electrical power systems. Different overheating issues and overheating faults produced by core clamping bolts in transformers and shunt reactors have been detected and analyzed [4]–[7]. For example, in [4] and [5], thermal failures produced in the connection bolts of core clamping structures of transformers are presented. During internal inspections, some regions with overheating evidence were detected in the connection bolts of core clamping frames. The insulation of these bolts failed, and high currents circulated in the bolts, producing high temperatures and overheating the regions of the bolts. In [6], a severe thermal fault produced by a melted core clamping bolt is presented. The stainless-steel clamping bolt was completely melted in the interior of the magnetic core of a transformer. The insulation of the bolt failed and produced a short circuit between the bolt and the steel laminations of the magnetic core, generating the circulation of high currents in the bolt. The circulation of these high currents melted an important portion of the clamping bolt. In [7], a thermal failure was detected in a core clamping bolt of a shunt reactor. The presence of gases was detected in the reactor using dissolved gas analysis (DGA). Parts of a core clamping bolt were found in one of the core clamps of the shunt reactor during an internal inspection. The bolt and some core steel laminations presented overheating signs. The clamping bolt was removed from the magnetic core, and the insulation of the bolt presented evident damage. In this case, the overheating failure was produced by the circulation of a high current in the bolt produced by a short circuit between the bolt and the laminations of the core and the steel clamping structure of the shunt reactor.

On the other hand, other interesting thermal failures produced by core clamping bolts have been detected in hydroelectric generators. For example, in [8], thermal failures in the stator core clamping bolts of a real hydroelectric generator were studied and analyzed using finite element (FE) simulations. The authors performed an internal inspection of the generator to detect and locate the thermal failures. Several stator core clamping bolts presented severe damage with visible signs of overheating and melting, while some bolts presented mechanical fractures. The insulation of the bolts was destroyed and carbonized. The main cause of the overheating failure was a short circuit between the bolts and the core bars, precisely where the insulation material was damaged and destroyed. When the insulation material between the core bars and the bolts was destroyed, a short circuit was produced between them. High currents circulated in the bolts and core bars, subjecting the bolts to high electromagnetic forces, producing mechanical vibration that eventually led to overheating and melting of the bolts of the generators.

In this article, the origin of a thermal failure in a core clamping bolt of a shunt reactor is presented, analyzed, and demonstrated using Multiphysics three-dimensional (3-D) finite element (FE) simulations. The process utilized to diagnose the thermal failure in the shunt reactor is presented. Utilizing electromagnetic and thermal finite element simulations, the author demonstrated that the thermal fault was produced by a short circuit between the bolt and one of the clamping frames producing the circulation of high current in the bolt and producing temperatures of almost 850 °C.

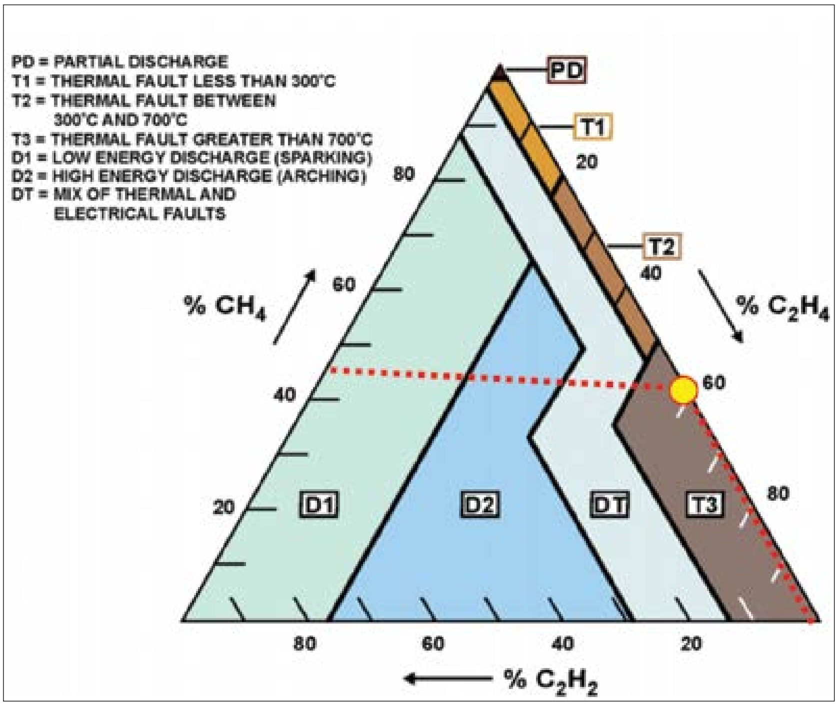


Figure 1. Identification of the thermal fault in the shunt reactor using Duval's triangle method

Overheating Failure in the Shunt Reactor

The presence of gases was monitored and detected in a 5 MVAr three-phase shunt reactor during its normal operation in a substation in Mexico [9]. Table 1 shows the characteristics of the shunt reactor [10]. Over five months, high amounts of hydrogen (H_2), ethylene (C_2H_4), acetylene (C_2H_2), and methane (CH_4) were detected in the shunt reactor, indicating the presence of a possible high-temperature fault. Table 2 shows the dissolved gas analysis (DGA) results obtained in the shunt reactor [9]. A thermal fault was confirmed using Duval's triangle method and the DGA results of Table 2. From Duval's triangle, a thermal fault type T3 was diagnosed in this shunt reactor, see Figure 1. A thermal fault type T3 indicates a failure in insulating oil and/or paper above 700 °C with evidence of carbonized oil, with metal coloration or melting. The possible causes for these thermal faults could generate overheating regions, partial discharges, and sustained electric arcs [11]-[13]. Despite the detection of gases in the shunt reactor, the Mexican electric utility company and substation operators decided to run the failure of the shunt reactor, which never fully occurred.

After detecting the thermal fault, the shunt reactor was put out of service, and the substation staff decided to send the shunt reactor for repair to the original manufacturer. An internal inspection was performed to locate the failure region in the shunt reactor. Clear signs of overheating were found in the region of one of the non-magnetic stainless steel clamping bolts in one of the top low-carbon steel clamping frames of the shunt reactor, see Figure 2 (a). The bolt presented evidence of carbonized oil and insulation residues, but it did not present cracks or evidence of melting. It indicates that the temperature of the clamping bolt reached temperatures below 1400 °C (melting point).

Visible signs of overheating were found in the region of one of the non-magnetic stainless steel clamping bolts in one of the top low-carbon steel clamping frames of the shunt reactor

The carbonized residue of insulation was found around the bolt region, with more found on the top coil region. The clamping bolt was removed from the top frame, and the manufacturer discovered that an important part of the insulation along the bolt had been damaged and destroyed, leaving the bolt bare, see Figure 2 (b). Generally, several layers of insulating paper are employed to insulate the clamping bolts from the core yokes and frames. The insulation along the bolt prevents possible contact between the bolt and the core frames and contact between the bolt and the magnetic core laminations. The author and manufacturer believe that the main cause of the damaged bolt insulation was produced by the loosening of the bolts produced by the vibration of the shunt reactor in conjunction with a low torque applied to the bolts during the tightening process [14]. The reactor vibration loosened the clamping bolt, damaging and destroying its insulation and producing a short circuit between the core frame and the bolt, generating the circulation of a high current in the bolt and generating high temperatures in the bolt-frame region. Thermal faults have been detected in high-voltage shunt reactors due to vibrations [15], [16].

To verify this assumption about the short circuit between the bolt and the frame, 3-D Multiphysics FE simulations were performed to verify the cause of overheating in the bolt of the shunt reactor. In the next sections of this paper, the results of the 3-D FE simulations will be presented, and the origin of the overheating fault will be demonstrated.

Table 1. Characteristics of the shunt reactor [9], [10]

Characteristic	Value
Number of phases	3
Nominal Power	5 MVAr
Nominal Voltage	115 kV
Nominal current	25.1 A
Frequency	60 Hz
Cooling system	ONAN
Top oil temperature	80 °C

Table 2. DGA results of the shunt reactor [9]

Gas, content	Dec 10th	Dec 12th	Dec 31st	Jan 31st	Feb 28th	Mar 31st	Apr 30th	May 31st
CO, ppm	80	90	130	160	175	195	210	215
H_2, ppm	80.5	186	760	3110	8500	10100	12700	12300
CH_4, ppm	123	317	1650	7220	19300	45500	64600	73100
C_2H_6, ppm	43.2	93.8	508	2420	5840	11000	17200	19100
C_2H_4, ppm	181	437	1800	7120	25900	51600	70500	78500
C_2H_2, ppm	1.8	2.4	2	9.4	34.2	163	153	262

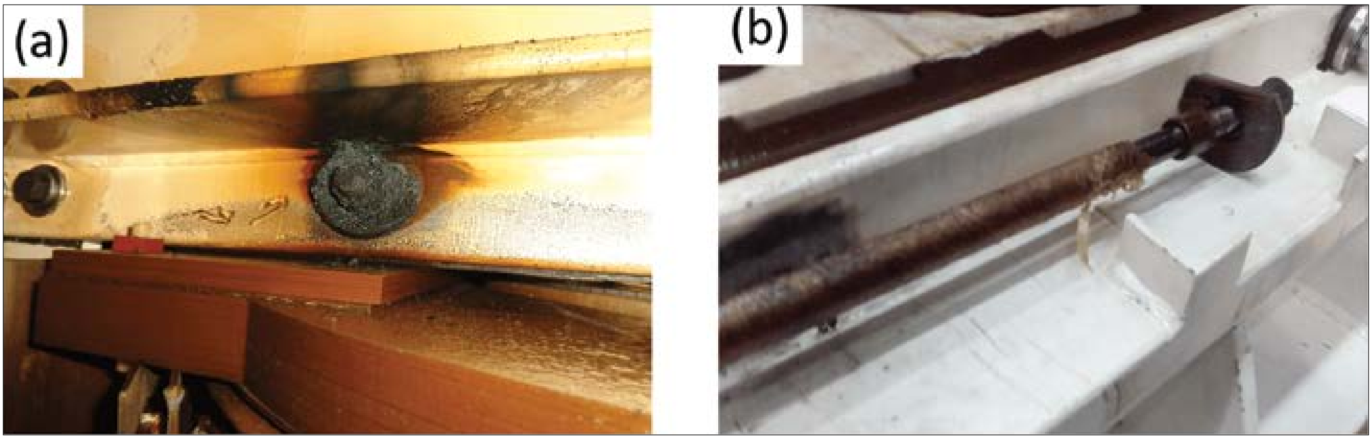


Figure 2. a) Bolt and frame with signs of overheating, b) insulation of the bolt destroyed [9]

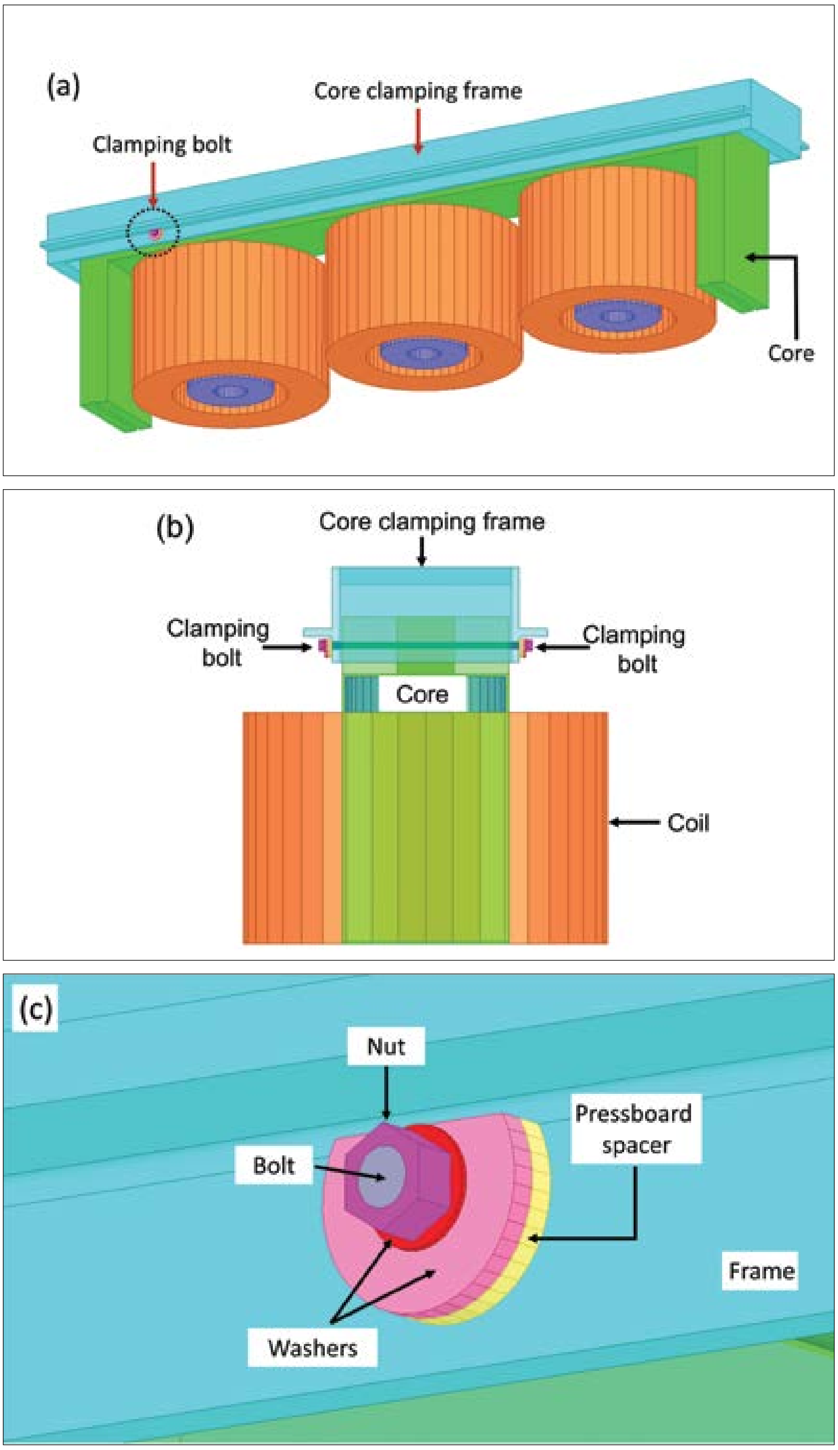


Figure 3. a) shunt reactor model, b) lateral view of the shunt reactor model, c) view of the clamping bolt region

3-D finite element electromagnetic and thermal simulations were performed to figure out the cause of overheating in the clamping bolt of the 5 MVAr shunt reactor

Multiphysics Analysis

3-D finite element (FE) simulations were performed to figure out the cause of overheating in the clamping bolt of the 5 MVAr shunt reactor. Time-harmonic FE simulations were performed to compute the power losses in the clamping system of the shunt reactor, including the power losses in the bolt. The current circulating in the bolt was computed in this analysis. Static thermal simulations were carried out to compute the temperature distribution in the clamping system and clamping bolt utilizing the power losses computed in the time-harmonic analyses. The Multiphysics FE analyses permit us to analyze the presence of hot spots or regions with high temperatures in structural parts of power transformers and shunt reactors [17], [18]. Moreover, the Multiphysics FE analyses permit us to analyze different techniques for the reduction of these hot spots or high temperatures in shunt reactors and power transformers, for example, magnetic shunts, electromagnetic shields, stainless steel inserts, etc.

The interest regions of the 3-D shunt reactor model are presented in Figure 3. The coils of the shunt reactor are made of copper conductors, and the magnetic core is made of laminations of grain-oriented electrical steel. The clamping frames are made of low-carbon steel, while the bolts, nuts, and flat washers are made of non-magnetic stainless steel.

Overheating Failure Analysis of Clamping Bolt

A single clamping bolt is modeled and put in direct contact with one of the clamping frame sides of the shunt reactor to simulate the short circuit conditions presented in the real shunt reactor. All the other clamping bolts are completely insulated from the frames, and no current is circulating through them. For this reason, these bolts are omitted in the model of Figure 3. A current density of 130 A/cm^2 and a short circuit current of 160 A were computed in the clamping bolt under short circuit conditions. This current circulates in the bolt, passing through the magnetic core holes. This current produces a small and saturated region with a magnetic flux density of 2 T around the magnetic core holes, see Figure 4.

Figure 5 shows the loss density distribution in the clamping frame region. A maximum loss density of 3000 W/m^2 was computed in the frame region in the bolt-hole region. Figure 6 shows the current circulating in the bolt during the short circuit between the bolt and the clamping frame of the shunt reactor.

A current density of 130 A/cm2 and a short circuit current of 160 A were computed in the clamping bolt under short circuit conditions

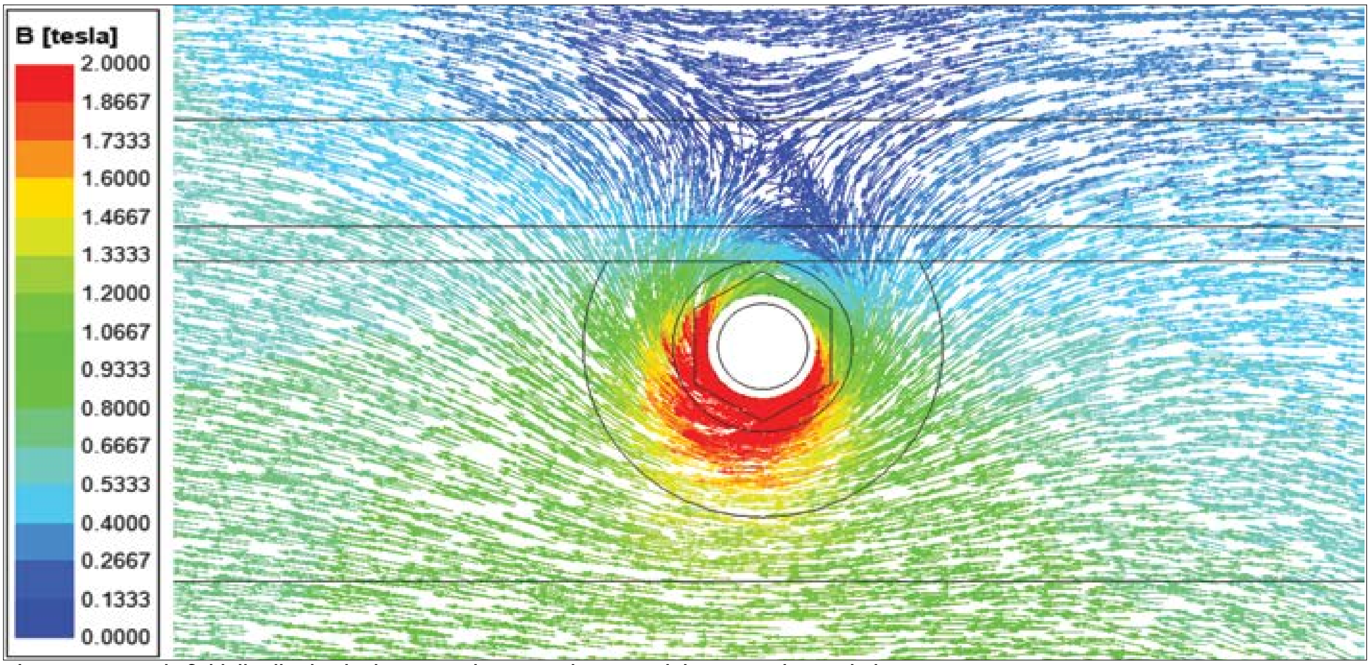


Figure 4. Magnetic field distribution in the magnetic core region around the magnetic core hole

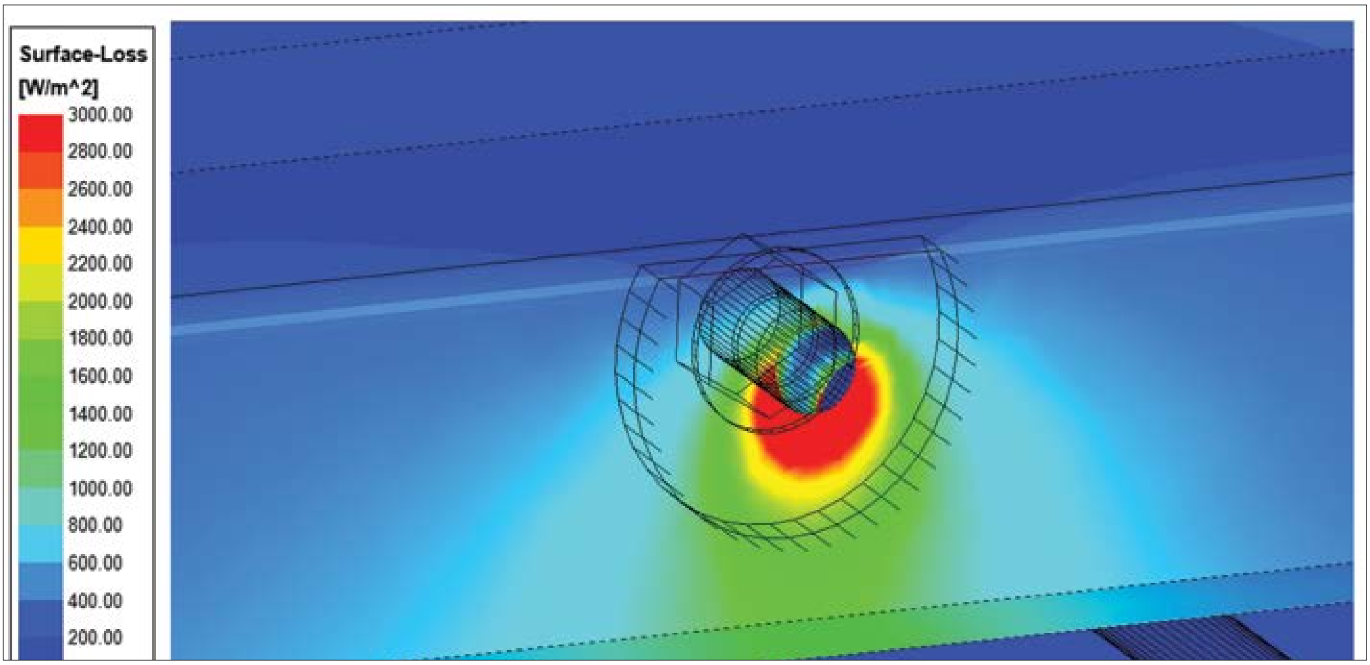


Figure 5. Loss density distribution in the bolt-frame region

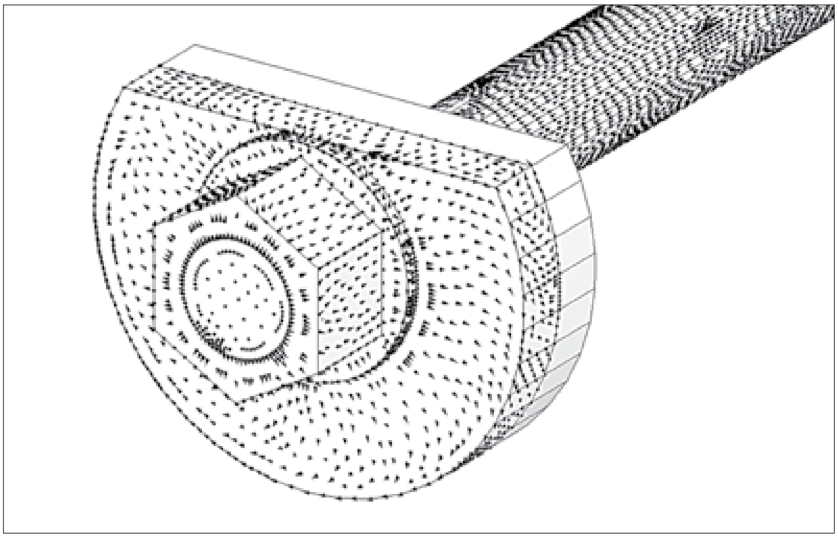


Figure 6. Short circuit currents circulating in the clamping bolt

The numerical calculations showed that the bolt reached an average temperature of 850 °C and a maximum temperature of almost 950 °C

Figure 7 shows the temperature distribution during the presence of the short circuit current in the clamping bolt. The bolt reached an average temperature of 850 °C and a maximum temperature of almost 950 °C. The poor circulation of the oil in the bolt-magnetic core region helped to increase the temperature of the bolt.

Based on the simulation results, the manufacturer decided to repair the shunt reactor, reinforcing the insulation of all the stainless-steel clamping bolts with several layers of fiberglass to prevent future short-circuit failures. In addition, the manufacturer replaced all the pressboard spacers with thick fiberglass spacers, and a bolt torque of 57 Nm was verified for all the bolts during the tightening process. Finally, the temperature of the repaired shunt reactor was monitored and tested in the high-voltage laboratory before shipping the shunt reactor to the customer.

Conclusion

In this article, the cause of the overheating failure of a clamping bolt in a high-voltage shunt reactor was presented and studied using Multiphysics finite element simulations. Because of the loosening of the clamping bolt produced by the vibration of the shunt reactor during its normal operation, the main insulation of the clamping bolt was damaged and destroyed, producing a short circuit between the bolt and the frame of the shunt reactor. A considerable short circuit current circulated in the bolt for a prolonged time, heating the bolt and the frame region where the short circuit was produced. The high temperatures in the bolt region broke down the oil and generated gases, and a thermal failure was diagnosed for the shunt reactor. Temperatures up to 800 ºC were estimated in the bolt region of the shunt reactor. Finally, the reactor manufacturer decided to reinforce the insulation of the clamping bolts to prevent the risk of future short circuit failures in the clamping bolts.

Based on the simulation results, the manufacturer decided to repair the reactor, reinforcing the insulation of all the stainless-steel clamping bolts with several layers of fiberglass to prevent future short-circuit failures

Acknowledgements

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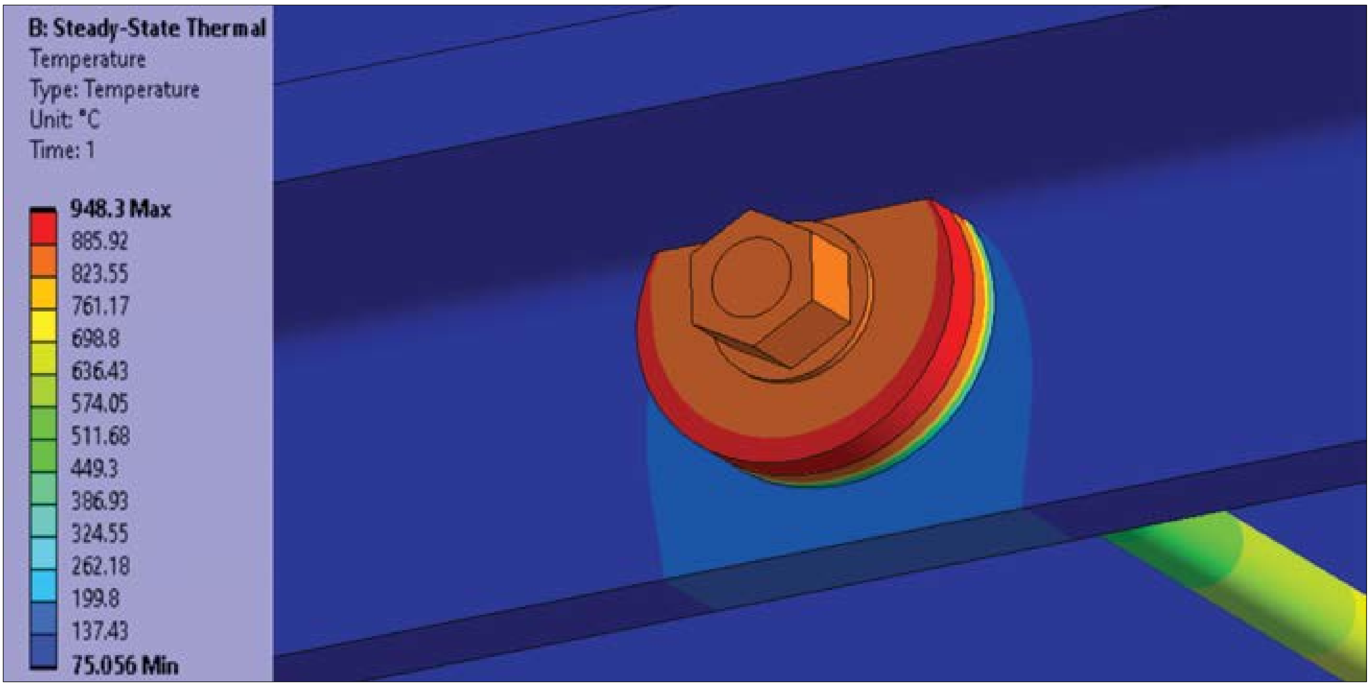

Figure 7. Temperature distribution in the clamping bolt and frame region

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PEER REVIEWED

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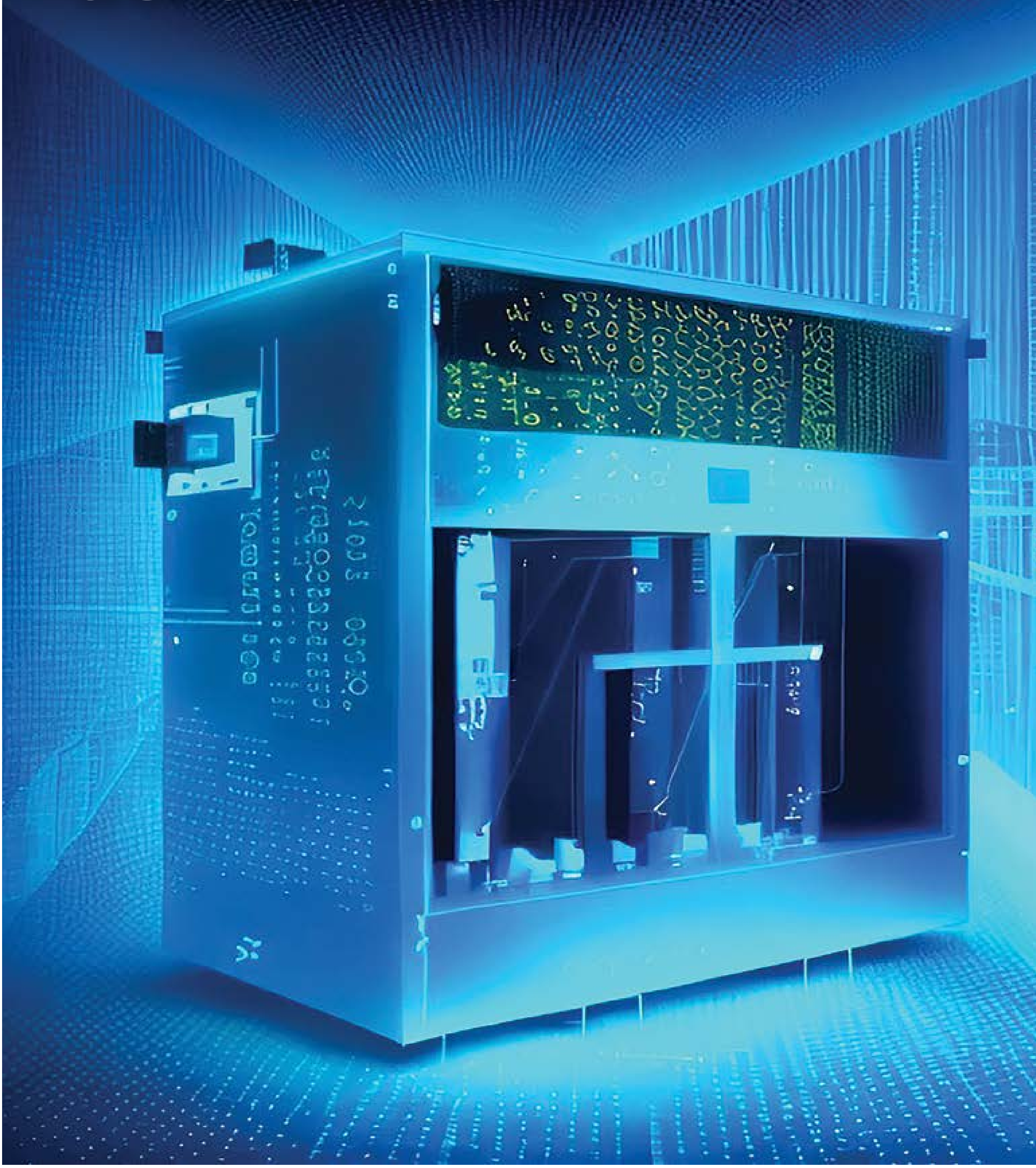
Digital twin of cast resin transformers



Mehran TAHIR

The electrical power system world is changing, and the power grid continues to increase in complexity by integrating intermittent renewables, distributed energy resources, electric vehicle charging stations, data centers

ABSTRACT

This article presents the benefits and development process of transformer digital twin applications to manage the current and future challenges to the transformer industry. Computer-aided engineering (CAE) tools such as the finite element method (FEM) simulations play a vital role in the development of transformer digital twins. HTT has developed DryTrafo, a digital twin application for cast resin transformers using multiphysics simulations. A three-phase rectifier transformer unit, 2000 kVA 10500/720 V is used to explain the development and working principle of the twin simulations under the portfolio of DryTrafo. These transformer digital twins can provide value in several stages, from planning and realization to field operations to help produce efficient designs, forecasting the transformer thermal behaviour under different load cycles, visualizing maximum permissible overload capabilities, and remaining useful life estimation.

KEYWORDS:

digital twin; cast-resin transformer; multiphysics simulation; FEM

A digital twin is a virtual replica of each physical transformer unit developed from the transformer design data

1. Introduction

In the past, grid conditions were quite stable, and transformers were therefore considered to operate under stable conditions in a centralized power grid. Due to stable load conditions, many transformers had a long lifetime. However, at present, the world is changing, and the power grid continues to increase in complexity by integrating intermittent renewables, distributed energy resources, electric vehicle charging stations, data centers, etc. All these factors result in more dynamic loading of transformers. Irrespective of the changing generation and demand trends, transformers are expected to last for 30-40 years. According to ABB, effective monitoring of a transformer can reduce repair costs by 75%, catastrophic failure by 50%, and lost revenue by 60%, while the annual saving of 2% of the price of a new transformer can be achieved with proper monitoring of the transformer [1]. However, manufacturers and asset owners feel the pressure to ensure competitiveness and effective allocation of capital and operational expenditures. Therefore, better insights are needed in order to ensure sound decisions on transformer design optimization, maintenance, repair, or new investment.

These challenges can be addressed by implementing smart and digital technologies, such as a transformer digital twin. In recent years, few transformer manufacturers have made efforts in power asset digitalization and asset digital twin developments, such as the Siemens Senseformer and the ABB Ability [1, 2]. These development activities in transformer digitalization support and remove uncertainty during design and configuration while supporting applications and ensuring availability and reliability through condition monitoring and advanced services.

2. What is a “transformer digital twin”?

A digital twin is a virtual replica of each physical transformer unit developed from the transformer design data. This replication is based on the design and operational data like winding current and voltages, type of insulation and cooling systems, ambient conditions, etc. Digital twins provide value in several stages, from planning and realization to field operations to help produce efficient designs, forecasting the transformer thermal behaviour under different load cycles, visualizing maximum permissible overload capabilities, as well as remaining useful life estimation, as depicted in Figure 1.

Computer-aided engineering (CAE) tools such as the finite element method (FEM) simulations play a vital role in the development of transformer digital twins as they shorten analysis and design cycles and assure optimized results by allowing a greater number of scenarios to be investigated. This reduces the time to market and overall cost. Moreover, these twin simulations help optimize transformer operations by simulating and forecasting transformer behaviour under various operating conditions. This provides improved operational reliability and productivity.

Hochspannungstechnik & Transformatorbau (HTT) makes extensive use of simulations in product development. Simulations cover a wide range of fields, including electromagnetics, thermodynamics, mechanics, fluid dynamics, and material science. Increasingly, simulations

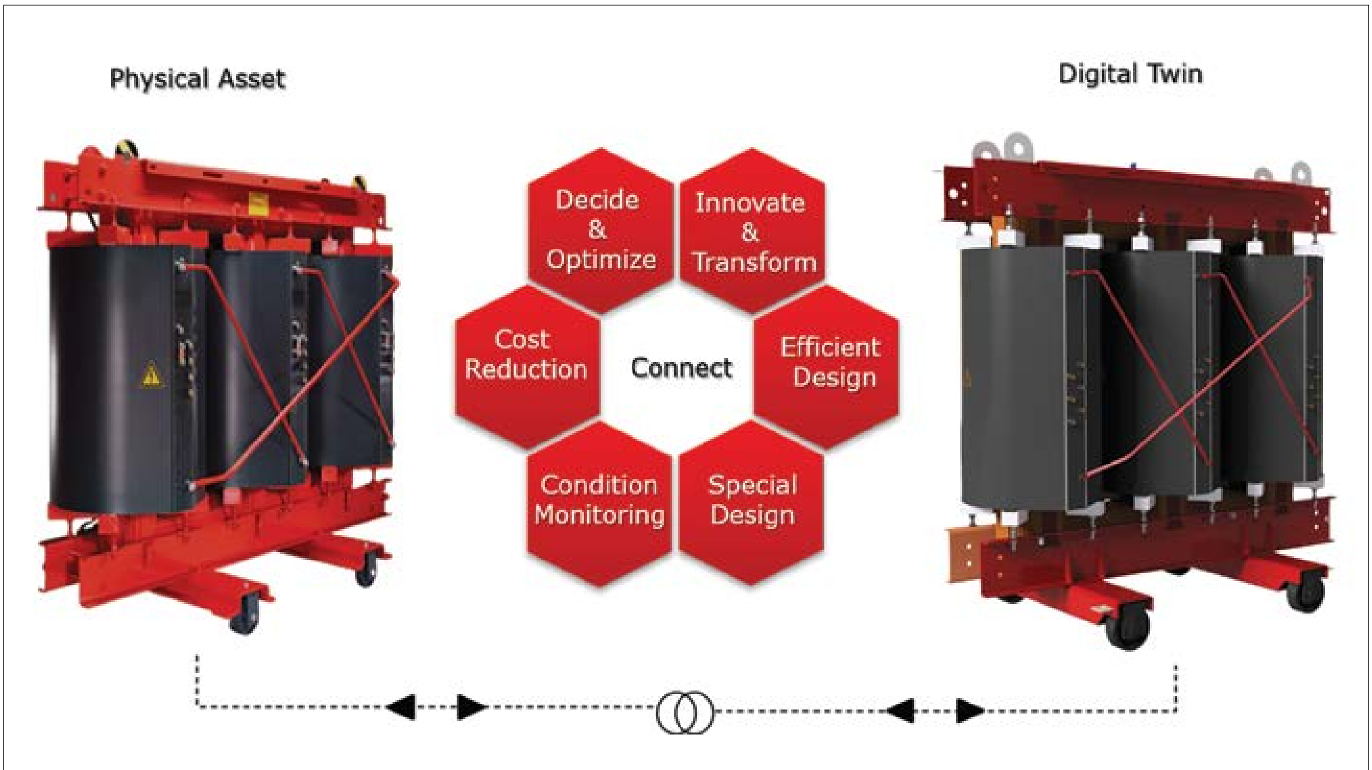


Figure 1. Transformer Digital Twin concept

also combine several of these domains and capture not only the sum of their effects but also the coupling and interactions between them in what is called multiphysics simulations. In 2022, HTT initiated a DryTrafo transformer digital twin project for cast resin transformers using multiphysics simulations [3]. Since then, various twin simulation applications have joined the portfolio, for example, electromagnetic simulations, power loss calculation, thermal analysis, hotspot temperature monitoring, etc. These tools provide more scope to be innovative, the possibility of testing a far greater number of variants and their combinations, experimenting with unorthodox approaches, enhancing the ability to make key decisions rapidly, and, of course, engaging customers with the specific designing and optimization of transformer operations during field utilization. This article looks at how a team of engineers at HTT develops multiphysics twin simulations and custom-built applications to develop transformer digital twins for their cast resin transformers.

3. Development of transformer digital twin

Several parameters must be considered before developing a transformer digital twin. Among them is the scale of the digital twin, e.g., component modeling or system level modeling, the type of predominant physics involved and their mutual coupling, input parameters such as design and operational data, computational accuracy, and finally, computation time, i.e., how quickly a twin model yields actionable information [4].

Another important aspect is the deployment of the digital twin, as the complexity of these tools limits their use to skilled users. With this in mind, HTT used the application builder tool to build specialized, easy-to-use shorthand apps from complex models. These applications are then shared with end users as standalone applications, which can run on a desktop or laptop computer without a COMSOL server license. In this way, the apps then make the simulation engineer's expertise available to everyone involved in the design and manufacturing processes across all engineering disciplines in the organization. Similarly, HTT has built various apps at different scales involving different dominant physics, and a graphical illustration of this is shown in Figure 2.

In this article, a three-phase rectifier cast resin transformer unit, 2000 kVA 10500/720 V is used to explain the development of twin simulations

In this article, a three-phase rectifier cast resin transformer unit, 2000 kVA 10500/720 V is used to explain the development of twin simulations. Figure 3 shows the schematic view of the transformer with basic components, where the low voltage winding is made of continuous aluminium strips (1) and high voltage winding is a foil winding separated by two layers of insulation material (2).

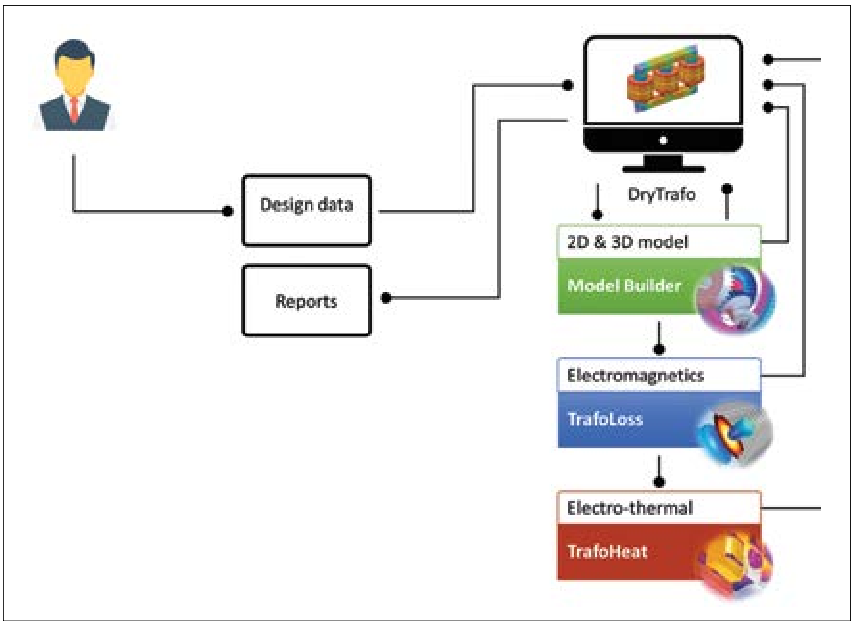


Figure 2. Graphical illustration of DryTrafo twin application

Figure 3. Schematic view of cast resin transformer with basic components

The simulation of actual transformer behaviour and computation of copper losses is carried out in COMSOL multiphysics software based on the finite element method

The major objectives in this process are as follows:

- Computation of power losses
- Dielectric performance assessment through electric field strength monitoring
- Thermal behaviour under various loading cycles and with different cooling systems
- Hotspot temperature analysis for temperature sensor installation
- Calculation of electromagnetic forces for fault analysis
- Ensuring optimized design and efficient electrical performance

3.1 Computation of power losses

Transformer losses can be classified into core losses, copper losses, and auxiliary losses. Core losses are mainly governed by hysteresis. Hysteresis losses are intrinsic to any magnetic iron core. These losses are maximum under the open circuit condition, as the maximum magnetic fields are induced in the core in this condition. However, the core may also experience losses because of eddy currents. These are generally smaller than hysteresis losses thanks to the use of laminated iron, which minimizes eddy currents. Copper losses are due to the electrical resistance of the conductor. These losses can drastically increase due to the skin and proximity effects. Auxiliary losses contribute to the losses that occur in metallic structures that support the transformer. In this article, the modeling of copper losses will be addressed in detail.

The simulation of actual transformer behaviour and computation of copper losses is carried out in COMSOL multiphysics software based on the finite element method [3]. FEM is a spatial discretization approach to numerically solve electromagnetic fields in the time and frequency domain and lead to a single solution. In this article, frequency domain study is used to solve Maxwell's equations. To emulate the actual measurement procedure, a short circuit test is simulated by shorting the LV winding and applying a voltage to the HV to ensure a nominal current flowing through the circuit in order to compute the copper losses in the transformer.

In the case of the three-phase cast resin transformer, the HV and LV windings are complex as well, as there is a large number of turns. While a reliable computation of copper losses demands explicit modeling of the detailed conductors to account for skin and proximity effects, such a detailed 3D model requires a large number of computation costs and time. However, the windings power loss and core loss distribution of each phase are almost the same, which is why only one of the three phases is supposed to be analyzed. Additionally, the structure of one phase is also axisymmetric. Thus, a 2D axisymmetric model which incorporates individual conductor domains to understand the current density of the conductors is developed. In this way, the solution time was significantly reduced. To gain confidence in the accuracy of the model, the adaptive mesh refinement feature is used, which allows the control of the mesh size and levels in different parts of the model. This strategy not only leads to a decrease in the use of computational resources but also increases the accuracy of the model.

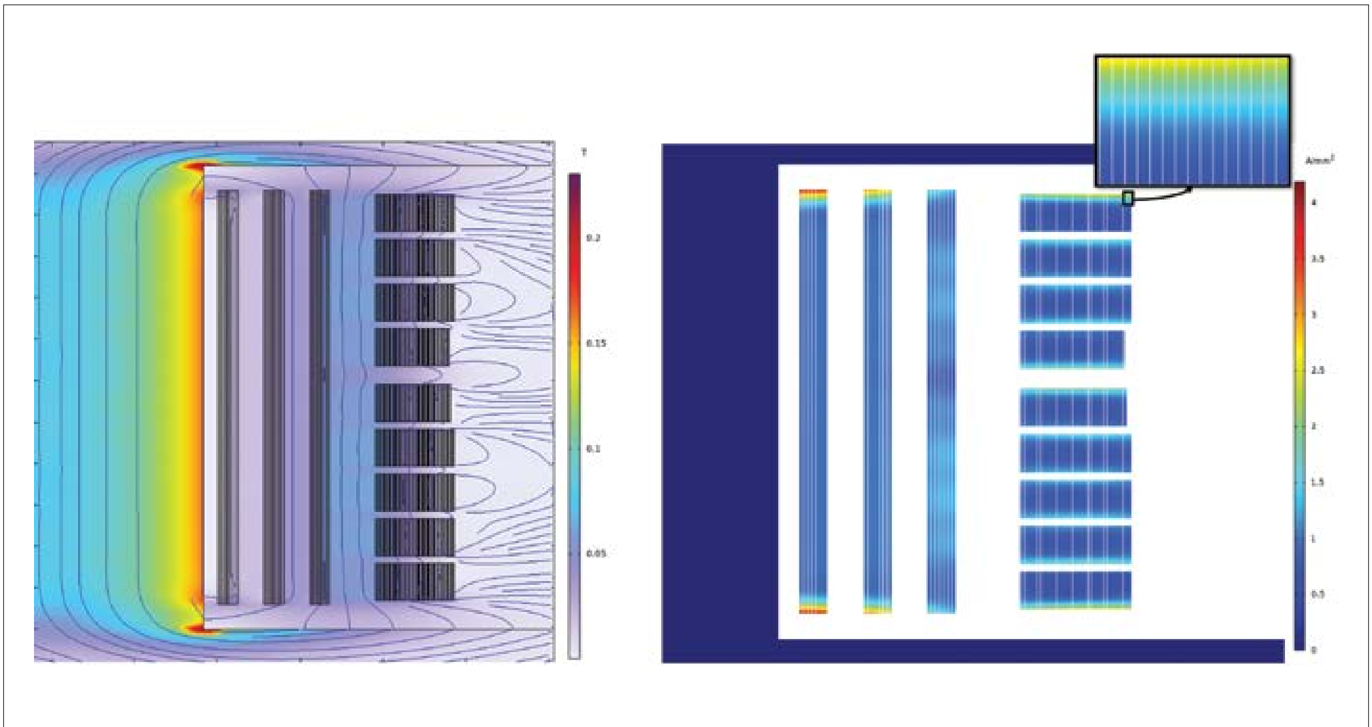


Figure 4. DryLoss twin application results of magnetic field density (left) and current density (right)

Figure 4 illustrates the simulation results of the TrafoLoss twin application. The results are validated with measurements at different stages. A comparison of simulation and measurement results is shown in Table 1. The TrafoLoss app can effectively replicate the transformer short circuit routine test with a maximum deviation of 5%. The key features of the TrafoLoss twin app are given below:

- Computation of DC and AC losses, which facilitates the design optimization as well as provides the opportunity to study the performance of different types of windings and their arrangements.
- Magnetic and current density fields provide a visual assessment to identify high and low-loss pockets in the transformer geometry.
- Generation of automatic reports, which facilitates the communication of results in the most readable format for designers.

Dry-type transformers' thermal performance is generally worse than that of oil-filled transformers due to their cooling medium (air) and the fact that they use natural convection for heat transfer

3.2 Thermal Analysis

Dry-type transformers are highly sensitive to temperature changes. Their thermal performance is generally worse than that of oil-filled transformers due to their cooling medium (air) and the fact that they use natural convection for heat transfer. The hotspot temperature determines the loading of the transformer, the aging of the transformer, and, thus, its remaining useful life. Therefore, it is imperative to have reliable thermal calculation tools at the designer's disposal to achieve an optimized design for dry-type transformers. With this in mind, HTT has developed a TrafoHeat twin application based on the maxwell-CFD multiphysics approach. HTT's TrafoHeat twin app can satisfactorily compute winding temperature rise, including hotspot temperature, by considering all details of winding, core, and cooling system within seconds.

Heat transfer in a cast resin transformer mainly involves conduction, convection, and radiation. The effect of heat radiation is much smaller as it is mainly reflected in

The TrafoLoss app can effectively replicate the transformer short circuit routine test with a maximum deviation of 5%

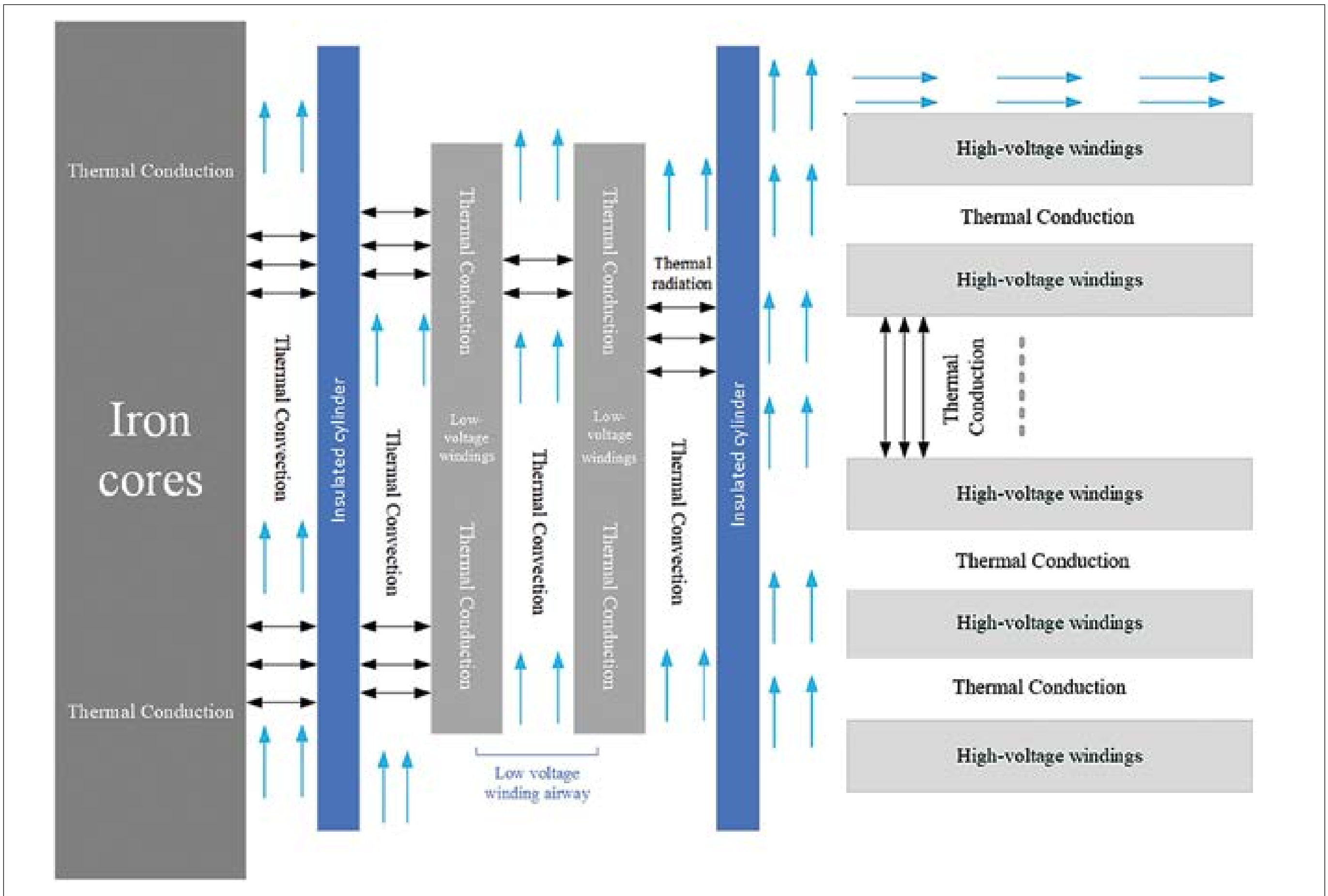


Figure 5. Transformer heat dissipation structure

Table 1. Comparison of simulation and measurement results

	Short circuit Impedance and short circuit losses (IEC 60076-1:2011, clause 11.4)		Winding temperature rise according to IEC 60076-2	
	Short circuit losses P_k [W] at 120°C	Short circuit impedance Uk [%]	System 1 ΔT_1 [K]	System 2 ΔT_2 [K]
Measurement	14202	6.19	85.1 K	80.6 K
Simulation	14441	6.05	88.3 K	76.5 K
Deviation	1.68 %	2.26 %	3.2 K	4.1 K

non-contact solid materials. During the operation of the transformer, the electromagnetic losses in the core, windings, and structural parts are the main heat sources of the cast resin transformers. The solid parts mainly transfer the heat to their surface by conduction and dissipate heat to the surrounding environment. Between solid and air-fluid, heat is mainly transferred by convection due to the temperature difference in both mediums. The internal heat dissipation phenomenon of a cast resin transformer is shown in Figure 5.

The TrafoHeat app considers all the physical phenomena that occur during the standard heat run test. For thermal calculations, it solves three physical field modules in the time domain to capture thermal images of the transformer, i.e., solid and fluid heat transfer, laminar flow, and surface radiation. Thanks to the multiphysics feature, these heat transfer studies are tightly coupled with electromagnetic physics, which takes into account the electrical losses, and skin and proximity effects, temperature effects on material resistivity are also considered. The temperature distribution of each component of the cast resin transformer is shown in Figure 6. In this figure, hotspot temperatures and their locations can also be identified in different components. The multi-component thermal analysis and multiphysics approach make TrafoHeat a different digital twin app from conventional thermal models. The simulation results are validated with the measurement results at different stages, as appreciated in Table 1. HTT's TrafoHeat app can satisfactorily capture the real-time thermal image of the cast resin transformer with a maximum deviation of 5 K from the measurement results.

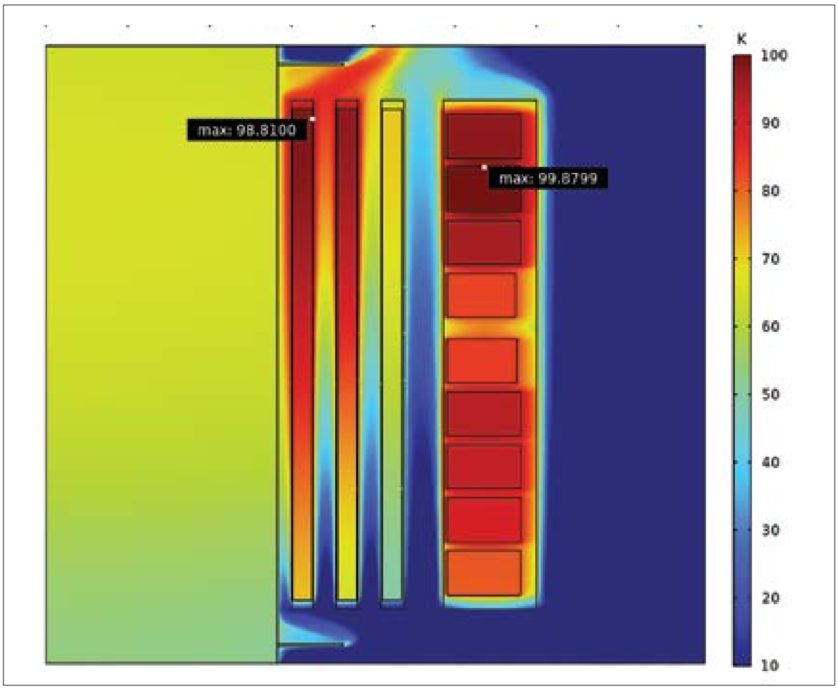


Figure 6. DryHeat twin application result of temperature distribution and hotspot indication

The multi-component thermal analysis and multiphysics approach make TrafoHeat a different digital twin app from conventional thermal models

Currently, the TrafoHeat app can be useful in the following scenarios:

- Analyzing the thermal behaviour of cast resin transformer
- Possibility of design optimization to reduce thermal stress
- Determining permissible overload capability with user-defined boundary conditions
- Monitoring hotspot temperature and their locations to install temperature sensors
- Forecasting thermal performance for different load cycles and ambient temperature cycles for 24 hours in the future.

4. Conclusion

The growing complexity of grids brings new challenges to the transformer industry, which can be mitigated by implementing smart and digital technologies such as a transformer digital twin. In this article, a three-phase rectifier transformer unit,

2000 kVA 10500/720 V is used to explain the development of digital twin applications, for example, DryLoss and DryHeat, under the portfolio of DryTrafo. DryLoss twin application computes AC and DC losses, and it also provides a visual assessment of magnetic and current density fields to identify high and low-loss pockets in the transformer geometry, which facilitates design optimization. DryHeat twin application analyses the thermal behaviour of cast resin transformers, including the identification of hotspot temperature. It is also valuable for determining permissible overload capability with user-defined boundary conditions and forecasting thermal performance for different load cycles. Another key feature is automated report generation. This facilitates the communication of results in the most readable format for designers.

In conclusion, DryTrafo offers insight into transformer designs and allows engineers to provide a complete optimization of transformer design within minutes. Further digital twin applications will follow in the near future, complementing the dynamic and new challenges to the transformer industry.

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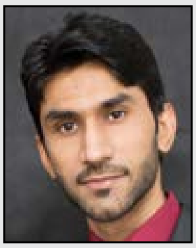

Mehran Tahir received his M.Sc. in power engineering from the Technical University of Munich, Germany, in 2016. In 2017, he was appointed as a scientific assistant at the Institute of Power Transmission and High Voltage Technology (IEH), University of Stuttgart, Germany. He completed his PhD work in High voltage engineering in 2021. In 2022, he joined Hochspannungstechnik & Transformatorbau GmbH (HTT) and worked as Head of Technology. At HTT, he is responsible for designing and calculating Dry and oil-immersed transformers and leading the R&D team. He is an active member of the IEEE, CIGRE SC A2 (Power Transformers).

Overcoming bottlenecks in digitalization for renewable energy and EV charging infrastructure

ABSTRACT

Economies all over the world are pushing to deploy greater renewable energy and electric vehicle charging infrastructure. This requires significant investment in the electrical grid infrastructure, which is expected to expand the market for grid digitalization. However, there are bottlenecks which stakeholders must remove before digitalization becomes widespread, including cyber security, workforce training, and costs. Currently, the digitalization of electricity is taking place largely at high voltages but is expected to be integrated at the medium voltage level in the future.

KEYWORDS:

digitalization; renewable energy; electric vehicles; charging infrastructure; grid investment

Azhar FAYYAZ

Economies across the globe, specifically advanced economies such as the US and EU member states, are rapidly deploying renewable generation and electric vehicles in order to combat climate change

According to forecasts by Power Technology Research (PTR Inc.), global renewable capacity is projected to increase by 60% for the five-year period 2018-2022 relative to 2023-2027

1. Introduction

Economies across the globe, specifically advanced economies such as the US and EU member states, are rapidly deploying renewable generation and electric vehicles in order to combat climate change. The Paris Agreement played a significant role in this regard. It is a legally binding international treaty on climate change that aims to curtail an increase in the global average temperature below 2 degrees Celsius relative to pre-industrial levels. The "stretch goal" is an increase of only 1.5 degrees Celsius [1]. Signatory countries have set ambitious targets in line with international commitments on climate change.

As countries push toward these targets, the demand for renewable energy generation and electric vehicles has grown over the years. In turn, this necessitates consideration of their impact on the power grid and how to manage it. Digitalization of the electricity grid has emerged as a solution which enables widespread integration of renewable generation and electric vehicle charging infrastructure in an efficient and reliable manner.

2. Developments in the market supportive of grid digitalization

Economies are pushing to decarbonize the power and transportation sectors in a bid to achieve net carbon neutrality over time. This is expected to drive significant growth in renewable generation capacity. In turn, more electric vehicles will increase the demand for charging infrastructure. The surge in deployment of renewable generation capacity and EV charging infrastructure is expected to spur digitalization.

2.1 Decarbonization

According to forecasts by Power Technology Research (PTR Inc.), global renewable capacity is projected to increase by 60% for the five-year period 2018-2022 relative to 2023-2027. In comparison, the global electric vehicle market is expected to grow with a Compound Annual Growth Rate (CAGR) of 20% from 2022 to 2030.

Notably, a global renewable generation capacity of approximately 1300GW was installed between 2018 and 2022. It is expected that 2000GW of renewable generation capacity will be installed globally between 2023 and 2027. As to utility-scale solar capacity, 390GW of generation capacity was installed between 2018 and 2022. In the future, 710GW of generation capacity will be installed from 2023 to 2027, according to PTR Inc.. On the other hand, additional wind power capacity between 2018 and 2022 accounted for 405GW. This includes onshore wind capacity of 355GW and offshore, 50GW. Going forward, PTR Inc. forecasts wind power capacity additions of 610GW from 2023 until 2027. This includes onshore wind of 490GW and offshore, 120GW.

Key economies across the globe have set ambitious targets for the deployment of renewable energy generation and EV chargers, including Germany, the UK, France, Italy, Spain, the Netherlands, Saudi Arabia, the United States, Canada, Australia, India, and China. Germany targets 80% of electricity generation from renewable energy sources by 2030, followed later by the goal of 100%. Germany also strives to install 1 million charging stations by 2030.

The UK aims to generate 100% of electricity from renewable energy sources by 2036 and install 300,000 chargers by 2035. France targets electricity generation from renewable energy sources at over 40% by 2030. France also aims to install 7 million EV chargers by 2030. Italy plans to increase the share of renewables to over 30% and install 30,000 EV chargers by 2030.

Moreover, Spain has an ambitious target of renewable energy generation to over 70% by 2030, followed by 100% generation from renewable energy sources by 2050. To cater to EVs in the Spanish market, it has set a target of 3 million chargers by 2030. The Netherlands plans to increase the share of renewable energy to over 70% by 2030, followed by 100% by 2050. To assist widespread deployment of EVs in the Netherlands, they plan to install 88,000 EV chargers by 2030.

The United States plans to generate 80% of electricity from renewable energy sources by 2030, followed by 100% by 2035. In order to pave the way for the widespread deployment of electric vehicles, the US aims to install 60,000 chargers by 2050 and 500,000 by 2030. Canada is pushing to increase the share of renewable energy sources to 90% by 2030. It also targets to install 5000 EV chargers by 2029. Australia is moving to increase the share of generation from renewables from 27% to 82% by 2060. They target to install 90,000 EV chargers by 2030. India is planning to install 500GW of renewable generation capacity by 2030, including 280GW of solar and 140GW of wind power.

Saudi Arabia aims to generate 50% of its electricity from renewable energy sources by 2030. China targets wind and solar capacity of 1200GW by 2030. State Grid targets to install 18,000 public chargers by 2025.

2.2 Grid modernization

Utilities across the globe are making significant investments in grid modernization with a focus on digitalization. A Distribution System Operator (DSO)

The United States plans to generate 80% of electricity from renewable energy sources by 2030, followed by 100% by 2035

Utilities across the globe are making significant investments in grid modernization with a focus on digitalization

in the UK, UK power Networks plans to invest USD 5.7 billion between 2023 and 2028. This includes USD 161 million allocated to the development and deployment of digital solutions [2]. A DSO in Spain, Endesa, plans to invest USD 13 billion from 2021 to 2030 on network digitalization and modernization, aiming to reduce network losses by 3% [3]. An electricity and gas DSO in Belgium, ORES is spending USD 810 million from 2021 to 2023 with a focus on energy flow measurement upgrades, remote electricity network reconfiguration, and fibre optics for telecommunications reinforcement [4]. HydroOne plans to spend USD 3.9 billion on grid modernization and digitalization in Canada [5]. Italian DSO ACEA plans to invest USD 1.275 billion from 2022 to 2024 in smart meters, new control centres, and digitalization through IoT and remote control [6]. At the same time, HEP - a Croatian national electric power company - plans to invest USD 1.17 billion from 2022 to 2031. HEP is digitalizing management systems in distribution control centres and distribution dispatch centres. This will be followed by the modernization of remote-control systems in power facilities [7]. To conclude, massive investments are being made globally to modernize electricity grids. This facilitates the integration of renewable energy and supports EV charging infrastructure, and will, in turn, drive the growth of the global digitalization market.

3. Challenges and barriers to growth

Besides investment challenges for grid modernization driven by decarbonization, the grid faces other challenges to digitalization. The market must cater to the challenges of cyber security, workforce training, and costs. Unless bottlenecks are removed, digital technologies will not be fully adopted in electricity grids.

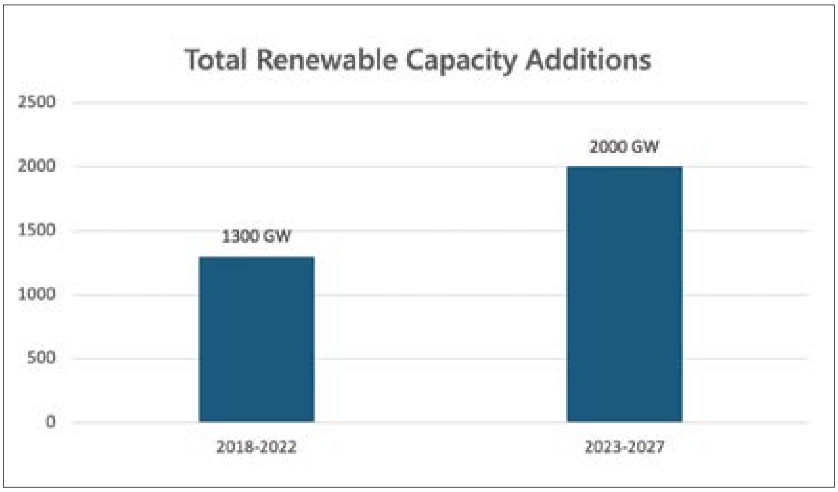

Figure 1. Total global renewable capacity additions.
Source: PTR Inc.

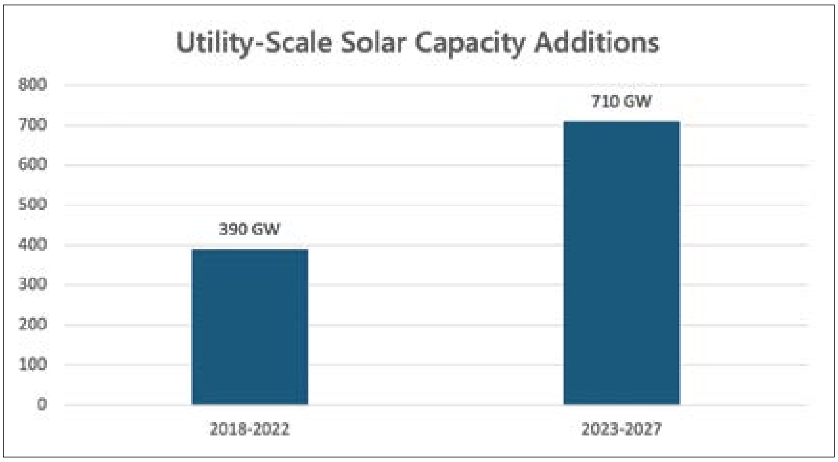

Figure 2. Total utility scale solar capacity additions.
Source: PTR Inc.

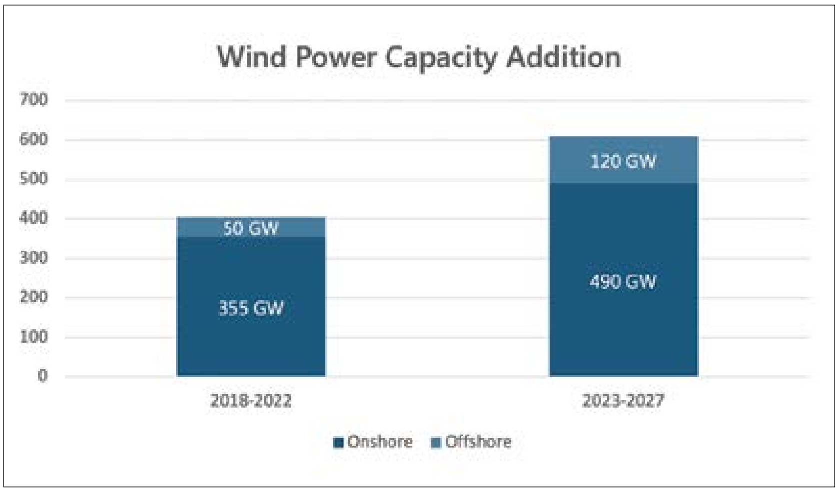

Figure 3. Total global wind power capacity additions.
Source: PTR Inc.

Besides investment challenges for grid modernization driven by decarbonization, the grid faces other challenges to digitalization

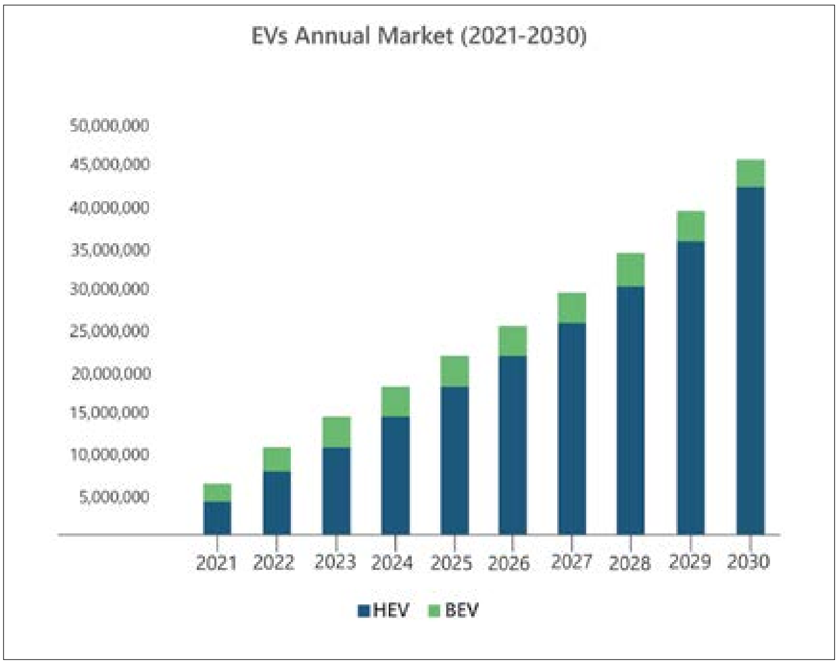

Figure 4. Global EV annual market (2021-2030).
Source: PTR Inc.

3.1 Cyber security

Cyber security is a serious concern for governments, utilities, and consumers: the data of millions of consumers could be leaked in a breach. The protection of electricity grid information is a national security concern. Cyber security must be prioritized and strengthened in order to avoid leakage.

Unless these concerns are addressed by stakeholders in the digitalization industry, market players will be reluctant to adopt the technology. In turn, this could hamper long-term climate goals. This holds true especially in the power sector, as digitalization is a key enabler for the deployment of renewable energy and the EV charging infrastructure.

3.2 Workforce training

Digital technologies are relatively new, especially for electricity grid equipment, and the utility workforce lacks training. Accordingly, initiatives should be taken to bring technician skill levels up to modern requirements.

3.3 Cost implications

The costs of integrating digital technologies into the electricity grid fall into three categories.

Simple advancement is achieved by installing sensors in grid equipment, for example, on conventional transformers.

Mid-level digital advancement is reached when both sensors and communication devices are installed on grid equipment.

This enables real-time monitoring.

High-level (and higher cost) digitalization entails the integration of sensors, communication devices, and data analysis software. As we move from low level to higher level digitalization, cost increases as well. It is critical for net cost to decrease in a manner that a business case can be made to integrate digital technologies with grid equipment.

4. Conclusion

Notably, digitalization is taking place mostly at high voltage. But it is expected to migrate to medium voltage levels. Recently, the Enel Infrastructure and Networks division opted to install the TXpert™ Ecosystem for the digitalization of transformers from ABB Power Grids. Installation of the TXpert™ Ecosystem not only improved the efficiency and reliability of transformers but also the connected grid [8]. The digital Ecosystem also helped optimize maintenance, in turn increasing equipment life.

Additionally, Hitachi ABB Power Grids has replaced a 50-year-old transformer with a TXpert™ enabled power transformer for Fortum [9]. The digitalized transformer is instrumented with temperature, pressure, oil condition, and voltage sensors to monitor and analyze its health, which improves performance and reliability. Similarly, in Chile, Hitachi ABB Power Grids' digital transformers are improving access to reliable and clean energy. It enabled major new wind and solar power projects in the country [10]. Mainstream Renewable Power's 1.3GW wind and solar platform Andes Renovables used digitally enabled transformers from Hitachi ABB Power Grids for the integration of sustainable electricity across nine of Mainstream's Chilean projects [10].

Market stakeholders must cooperate to remove bottlenecks such as cyber security concerns, workforce training, and costs to enable widespread digitalization. Cyber security will be a major concern for import-dependent markets (for power transformers) which have conflicts, like the United States. Workforce training will be required globally. As to digitalization cost, it will be a major concern for utilities in developing countries which have limited budgets.

Market stakeholders must cooperate to remove bottlenecks such as cyber security concerns, workforce training, and costs to enable widespread digitalization

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The 100th meeting of NEC 10 since 1924

Dutch Standards Committee

ABSTRACT

The Dutch standards committee NEC 10 follows the international IEC TC 10. During one hundred years, the topics and scope changed as they were developed. In this article, we highlight the trends in technology since its establishment in 1924.

KEYWORDS:

insulating fluids; standards, NEC, IEC

The NEC was established on March 17, 1911, allowing the Netherlands to actively participate in international electrotechnical standardization within the IEC

From insulating oils to fluids for electrotechnical resources – The NEC 10 standards committee celebrated its 100th meeting.

TC 10 is one of the oldest IEC Technical Committees, established in 1924 and initially named "Transformer oils", obviously reflecting the only practical application of that era

1. History

In 1886, the first public electric street lamps in the Netherlands were lit at the Waalkade in Nijmegen. The power was generated in the first power station in the Netherlands by Willem Smit & Co.'s Transformers NV in Nijmegen under the direction of Ir. Rosskopf. He was a pioneer in building transformers and was also one of the co-founders of the Dutch Electrotechnical Committee (NEC) . The NEC was established on March 17, 1911, allowing the Netherlands to actively participate in international electrotechnical standardization within the International Electrotechnical Commission, IEC . One of the oldest standards committees is NEC 10, which was created around the same time as the IEC TC 10 in 1924 . NEC 10 is celebrating its 100th meeting and its almost 100-year anniversary.

2. Scope

The Dutch standard committees align with the international IEC TCs. The scope of TC 10 and NEC 10 is to prepare product specifications, test methods, and maintenance and usage guides for liquid and gaseous dielectrics. They also prepare specifications, maintenance, and usage guides for lubricants and control fluids for steam turbines, generators, and control systems. Additionally, they assist in the preparation of test methods for such fluids.

3. Writing history

TC 10 is one of the oldest IEC Technical Committees, established in 1924 and initially named "Transformer oils", obviously reflecting the only practical application of that era. In 1926, the title and the scope were expanded to include "Insulating oils". In 1961, the Chairmen of TC 10 and TC 15 reached an agreement based on which all matters concerning liquid and gaseous dielectrics would be handled by TC 10. This agreement fostered a permanent liaison between the two IEC committees, TC 10 and TC 15. In 1964, it was decided that TC 10 would also deal with insulating liquids other than oils and with insulating gases, including askarels, silicone fluids, synthetic dielectrics, sulfur hexafluoride and others. In 1966, three sub-committees were established to study the various insulating fluids:

- SC 10A: Insulating hydrocarbon oils
- SC 10B: Insulating liquids other than hydrocarbon oils
- SC 10C: Insulating gases

In 1980, the scope was extended to include lubricants for turbines and control fluids, thus prompting a name change to "Fluids for electrotechnical applications". The most recent reorganization of TC 10 took place in 1987 when all the sub-committees were disbanded, and all work was placed under the responsibility of the Secretary of TC 10. TC 10 publications, which include about 50 documents ranging from International Standards to Technical Reports, fall into the following 3 categories:

- Test methods
- Specifications
- Maintenance and use guides

Recent work for NEC 10 was to approve the standard for natural esters, as an increasing number of transformers in the Netherlands are also being used with these specific liquids

4. Trends in technology

The constant increase in the power of electrical equipment combined with reductions in size and manufacturing costs means that insulating fluids must satisfy increasingly demanding performance requirements. Product specifications, as well as the usage and maintenance guides, must be adapted to these requirements.

As also reported in the TC14 SBP, natural ester-based insulating fluids began to be used commercially in North America for small transformers, while their application for larger power transformers is under development. Important applications have been made, especially in South America. A significant advantage of this fluid is its greater environmental friendliness compared to mineral oil.

Recent work for NEC 10 was to approve the standard for natural esters, as an increasing number of transformers in the Netherlands are also being used with these specific liquids. Changes are planned for synthetic esters, which NEC 10 will monitor, review, and approve.

Additionally, more recent technologies now allow for the design and construction of advanced units, such as special transformers and shunt reactors, which operate at very high temperatures. This necessitates the use of insulating liquids with much higher performances, like those with a higher "fire point"."

The rapid proliferation of online and offline monitoring systems and the need for a more reliable diagnosis of HV strategic equipment, which generally still uses oil-paper insulating systems, require possible rapid standardization of simpler or alternative oil tests. Alternatively, an advanced approach to interpreting tests on insulating fluids could be introduced in the Standards to facilitate the use of these online and offline technologies.

When it comes to mineral oil, however, there have also been remarkable changes regarding its further classification into different qualities, such as standard- and high-grade oils. This is in contrast to earlier times when only one base oil type was mentioned. This relevant standard also offers the possibility of using recycled oil. The reuse of insulating oil was specifically documented in England in a British Standard around 2013. This concept was initially met with scepticism in the Netherlands, especially concerning the traceability of this reusable oil and the miscibility of different oil qualities. However, there was considerable pressure from the IEC to swiftly adopt this standard within the involved maintenance team. As always, this team comprised a diverse international group with highly committed individuals and a range of languages. NEC 10 was also involved (IEC-60296).

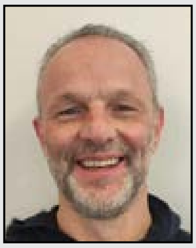
Very recently, trends in oil quality monitoring have evolved, and NEC 10 has contributed to updating the relevant standard (IEC 60422). Important changes include adjustments related to water content in oil and further classifications with the addition of tap changers, circuit breakers and switchgear, as well as bushings. The effects of water content on transformer paper and oil temperature have been thoroughly assessed under various operating conditions.

5. Anecdote

Here is a short anecdote from one of the members of the Maintenance Team of IEC 60296 and member of NEC 10, Mr. P. Salverda of TenneT: “During my time as a member of the NEC 14 committee, I was involved in merging the standards for new and reusable oil, namely the IEC 60296 standard. There was considerable pressure from the IEC to quickly adapt this standard within the Maintenance Team 38 (MT38). This involved many oil suppliers, some transformer manufacturers and end users. It was indeed an international company, with English as the working language. Imagine discussing content with a German chairman, Italian, Dutch and French experts, but also with team members whose native language is English. In those circumstances, language can sometimes be an obstacle. The meaning and connotation of certain words can vary significantly based on one’s native language. It was also notable that various participants would sometimes revert to their own language or even use dialects during discussions. This resulted in some interesting misunderstandings that one does not encounter every day. Luckily, we always came to an agreement, likely because all participants hailed from Europe and had a common understanding across borders. The membership in this MT gave me a lot of insight into insulating oil laboratories.”

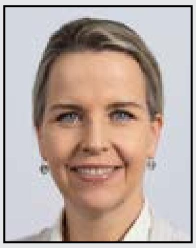
Very recently, trends in oil quality monitoring have evolved, and NEC 10 has contributed to updating the relevant standard (IEC 60422)

Authors



Pieter de Bijl is a senior insulation consultant at Royal Smit Transformers in Nijmegen, The Netherlands. He is also the chairman of the standards committee NEC 10 - Fluids for electrotechnical applications. He is a member of Cigre WG47 (New frontiers of Dissolved Gas Analysis (DGA) interpretation for power transformers and their accessories), and a member of IEC/TC10/MT25 Maintenance of IEC 60475, IEC 60567 and IEC 61181, member of IEC/TC10/MT20 Maintenance of IEC 60475, IEC 60567 and IEC 60599. He is a former member of IEC/TC112/WG6 (general methods of evaluation of electrical insulation).

Philip Salverda is asset manager at TenneT TSO BV, a technologist, transformer and reactor specialist. He is a member of the standards committee NEC 10 - Fluids for electrotechnical applications, and a member of IEC/TC10/MT38 Maintenance of IEC 60296 and of CLC/SR10 (Fluids for electrotechnical applications).



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My Transfo 2023: A return to knowledge sharing

Rekindling connections after 5 years

The transformer industry witnessed another gathering of experts this year at My Transfo 2023. After a long, five-year hiatus, which was in part attributed to the global pandemic, the highly anticipated event marked its return. The excitement could be heard in the voice of Cristina Tumiatti (Business Development Executive of Sea Marconi), the opening speaker. Conceived and organized by Sea Marconi since 2002 and always held in Turin, Italy, My Transfo 2023 was not only a testament to the resilience of the transformer and insulating oil industry but also highlighted its ongoing commitment

After a long, five-year hiatus, which was in part attributed to the global pandemic, the highly anticipated event marked its return

to sustainability, asset, risk, and solutions, which were the four main pillars of this year's edition.

In Cristina Tumiatti's opening speech, she expressed her gratitude for partnerships and sponsorships. The speech drew attention to the conference's most prominent sponsors in particular, including Omicron, COMEM, DASOTEC, A&A Fratelli Parodi, Doble, and DEPUROLL. Reflecting My Transfo's greener ethos, the attendees of the conference were welcomed with eco-friendly gestures like water bottles and reduced paper footprints. "Drink easy and sustainable, just like sampling" was the slogan that every My Transfo participant read on the foldable water bottle they received, along with an invitation to fill it at the water dispensers and reduce plastic usage. This phrase perfectly combines environmental awareness, which has always been a part of Sea Marconi's identity, with the launch of the new ISA (Inspection Sampling Audit) kit for inspections and sampling of transformers with insulating fluids. It's no coincidence that the water bottle distributed at My Transfo closely resembles the innovative element of Sea Marconi's new kit, which consists of an innovative, flexible bag that reduces shipping costs and waste production, especially when compared to aluminum bottles.

Vander Tumiatti's keynote speech

In his keynote speech, Vander Tumiatti, the founder and general partner of Sea Marconi, took the attendees on a journey that traced the growth of My Transfo, its global outreach, and the great significance of transformers in today's world. What stood out in his address was the breadth of Sea Marconi's initiatives, spanning Turkey, Japan, Poland, Argentina, and South America.

He gave insights into the three areas of risk in the transformer lifecycle, those being financial, fire, and environmental, while also proposing potential solutions for mitigating these risks and emphasiz-

The idea behind the creation of My Transfo in 2002 was the need to have a meeting point for industry professionals to share experiences and find solutions to emerging issues

ing the importance of innovation, best practices, and eco-sustainability. In his speech, Tumiatti also reminded the attendees of important historical figures such as Aurelio Peccei and Nikola Tesla and their innovations, thus emphasizing the ever-evolving nature of the industry and the real and urgent need for more sustainable solutions.

Technical contents

The idea behind the creation of My Transfo in 2002 was the need to have a meeting point for industry professionals to share experiences and find solutions to emerging issues to which industry standards, with a slow approval process, could not respond.

This fundamental principle has remained in every edition of My Transfo, and in 2023, one of the critical issues to address was the corrosion of the silver contacts of OLTC (On Load Tap Changers). Sea Marconi is one of the world's leading experts on corrosion phenomena, having discovered DBDS in 2005 as the primary cause of failures related to sulfur corrosion (C1). In the last 2 years, Sea Marconi has provided assistance and been directly involved in several cases of corrosion-related failures on the silver contacts of

OLTCs, with significant consequences in terms of damage and production loss. Known cases occurred in 2021 and 2022; in Europe, there was a catastrophic failure on a 440 MVA, 400 KV GSU step-up transformer with evidence of silver sulfide on the selector contacts, and the same evidence was found in Brazil, Colombia, and Argentina on highly strategic 500 KV HVDC equipment. These events add to the cases of failure mentioned in an IEEE article from 2021 that states, "In Australia, most transformers that have suffered failures due to silver sulfide corrosion were originally filled...". Sea Marconi has identified and defined a new pathology: "C5 - Corrosion of silver contacts from total sulfur compounds."

In this regard, My Transfo 2023 had the pleasure of hosting Sameera Samarasinghe, Asset Strategy Engineer at the Australian company Energy Queensland, who is one of the authors of the article on the cases in Australia mentioned above. In his presentation, Sameera Samarasinghe helped understand this significant issue, identifying new risk assessment strategies. The topic was further explored with the contribution of Vojko Mrdic, Application Engineer at DV Power, who proposed the DVtest (DRM) method for detecting bad contacts in OLTCs. The corrosion theme also featured the presentation of Omar Ali Al-Ghamdi, Director of GCC Technical Services at the Saudi company GCC Lab, which assists the Saudi national transmission network in asset management. Omar Ali Al-Ghamdi outlined the maintenance strategy adopted by the Saudi electrical grid to prevent the loss of large transformers caused by corrosive sulfur. Based on international standards and the local context, the most effective long-term mitigation technique was found to be selective depolarization by Sea Marconi. This technique has been proven to remove DBDS and oil corrosive compounds and restore all chemical and physical properties of the oil, even after a year.

Closing speech

During his speech at the end of the conference, Vander Tumiatti returned to the stage to express his gratitude. He

expressed his appreciation for everyone involved in My Transfo, including the speakers and attendees. The spotlight on the two organizers, Stefano Girolamo and Enrica Bertero, and a mention of the host venue highlighted the human element involved in making the event successful and memorable.

In a way, My Transfo 2023 was a celebration of collective knowledge, shared experiences, and renewed hope for a more sustainable future in the transformer industry

"It has been a great pleasure and a great satisfaction to see the surprise in the eyes of My Transfo participants during the exclusive evening visit to the Royal Palace of Turin. My Transfo is not just about high-level technical content but also about beauty, culture, and relationships.

We are well aware that there are many industry events worldwide, all quite similar to each other. My Transfo is probably the only event in Europe with simultaneous translation into three languages. Furthermore, it is held every two years precisely to avoid repetition and provide participants with genuine industry innovations and, if possible, solutions to take home and apply in their daily work from the very next day. Even the way we present the content and structure the agenda is meticulously planned. In fact, the two conference days are interspersed with more relaxed moments, and this year, the surprises we had prepared truly hit the mark.

One of the compliments that fills me with pride the most is hearing from those who have participated in previous editions that they thought it couldn't get any better than the previous one, but surprisingly, we manage to do so every time" - Stefano Girolamo said.

Meanwhile, Tumiatti emphasized the familial essence of Sea Marconi and acknowledged his family, especially his wife and daughters, which was a personal touch that must have impressed many attendees. His concluding remarks painted a vivid picture of My Transfo's past, present, and its promising future, and he didn't forget to remind the attendees to come back again in 2025.

Conclusion

My Transfo 2023 was a great success. According to the responses from the attendees in a post-event survey, the average note for the conference was 4,71/5. It can be said that it was also a celebration of collective knowledge, shared experiences, and renewed hope for a more sustainable future in the transformer industry. The attendees took with them valuable insights, knowledge, and a sense of commitment to a greener and brighter future for the industry and for the world.

Stefano Girolamo, Communication Manager at Sea Marconi and one of the organizers of My Transfo 2023

The aim of the Navigator 2024 conference is...

...to bring together key stakeholders in order to better understand and quantify future market dynamics. With better insights, the industry will be better able to navigate through challenging market conditions.

Key topics that the conference includes:

- Procuring transformers during market shortages
- Investments in new manufacturing capacities
- Artificial Intelligence
- Digitalization
- Asset Management
- Energy transition
- Decarbonization
- Circular economy
- Increasing efficiency

Data-driven industry analysis

The conference project involves in-depth analysis of critical industry challenges. This culminates in a comprehensive report that provides an invaluable basis for informed decision-making on investments, strategic development directions, and more.

Why present at the conference?

This conference is an independent platform, where you will have the opportunity to participate in an invitation-only Chatham House Rule meeting, advocate your views and influence future practice through debate.
You will also be among the first to receive research findings that will provide insight into the current situation and future actions.

I'm interested in presenting:

Please scan QR code for more info.

Vlatka Šerkinić
Sustainability Specialist,
Končar D&ST

Why attend the conference?

The conference provides a supportive environment, ideal for expanding your professional network, making contacts and deepening relationships with key industry leaders and peers.

At this conference you will have the opportunity to learn about future practices and take part in a public debate with other industry stakeholders. You can also participate in workshops and a study visit, and enjoy a rich social programme with great networking opportunities.

Moreover, you will have the chance to participate in the research that will provide insight into the current state and future actions relating to investments, sustainability and digitalization.

I'm interested in attending:

Please scan QR code for more info.

Why sponsor?

Collaborate with us to pave the way for a sustainable future in the transformer industry by becoming a Navigator Conference Sponsor . Sponsorship will associate your company with a meaningful initiative and ensure prominent exposure in our magazine, academy, website, social channels and event resources, including emails and web pages. After the conference, you'll receive an attendee list, a conference report and either a full page or half page advertisement in the final report.

Sponsorship options

Parties interested in supporting investments, sustainability or digitalization are welcome to sponsor this event by choosing one of the available packages.

SPONSOR	PARTNER	CHAMPION
DELIVERABLES: • visibility in conference materials • list of attendees • conference fee for 1 speaker	DELIVERABLES: • visibility in conference materials • list of attendees • report 2024 • half-page ad in the report once it's published • conference fee for 1 speaker	DELIVERABLES: • the most prominent place in conference materials and a podium • list of attendees • report 2024 • full-page ad in the 2023 report once it's published • conference fee for 1 speaker • article in the Transformers Magazine related to the presentation at the conference

For all last conference sponsors, the sponsorship packages additionally include:

SPONSOR	PARTNER	CHAMPION
• conference fee for 1 person	• conference fee for 2 persons	• conference fee for 3 persons

Previous events

Previous Navigator conferences have been vibrant events with a rich technical and social programme, supported by industry-leading companies.

Utilities:

EDF · Terna · HOPS

Transformer manufacturers:

Hitachi Energy · SIEMENS energy · SGB-SMIT Group · KONČAR · GANZ

Suppliers:

thyssenkrupp · ERGON HyVolt Dielectric Fluids · FR3 a Cargill brand · NYNAS · DYNAMIC RATINGS · MIDEL SAFETY INSIDE · MR · PTTX · MICAFLUID

Trade shows:

Coiltech International Coil&Winding Exhibition · CWIEME BERLIN

Testimonials

"I would hereby like to thank you for the opportunity to participate at the conference. Also, thank you for all the hard work you put into its organization; it was excellent. Everyone I spoke to was very satisfied.
We're looking forward to next year!"

Vlatka Serkinic, Sustainability specialist in Koncar Distribution and Special Transformers Inc.

"Thank you so much for hosting the Sustainability and Digitalization conference last week and inviting Ergon to do a presentation. The topics were very informative and I gained a great deal of insight into the sustainability efforts going on in the industry. It was very apparent that a great deal of planning went into the event and I wanted to congratulate you on the successful organization. Since I am new to the area of transformers and attended without a colleague, I especially appreciated the social aspects of the conference. The social outings made all the difference for me! Please give my thanks to the rest of your team as well."

Dr. Kristie Armstrong, Technical Project Manager and sustainability specialist, Ergon

"Transformers Magazine has succeeded in bringing key transformer industry stakeholders together to discuss the strategic trends shaping the industry. There was a real need for that and I am pleased to see that we have such a discussion platform now. I hope these events will become a tradition and will attract even more participants in the future."

Ufuk Kivrak, Consultant, SCM Consulting


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