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

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

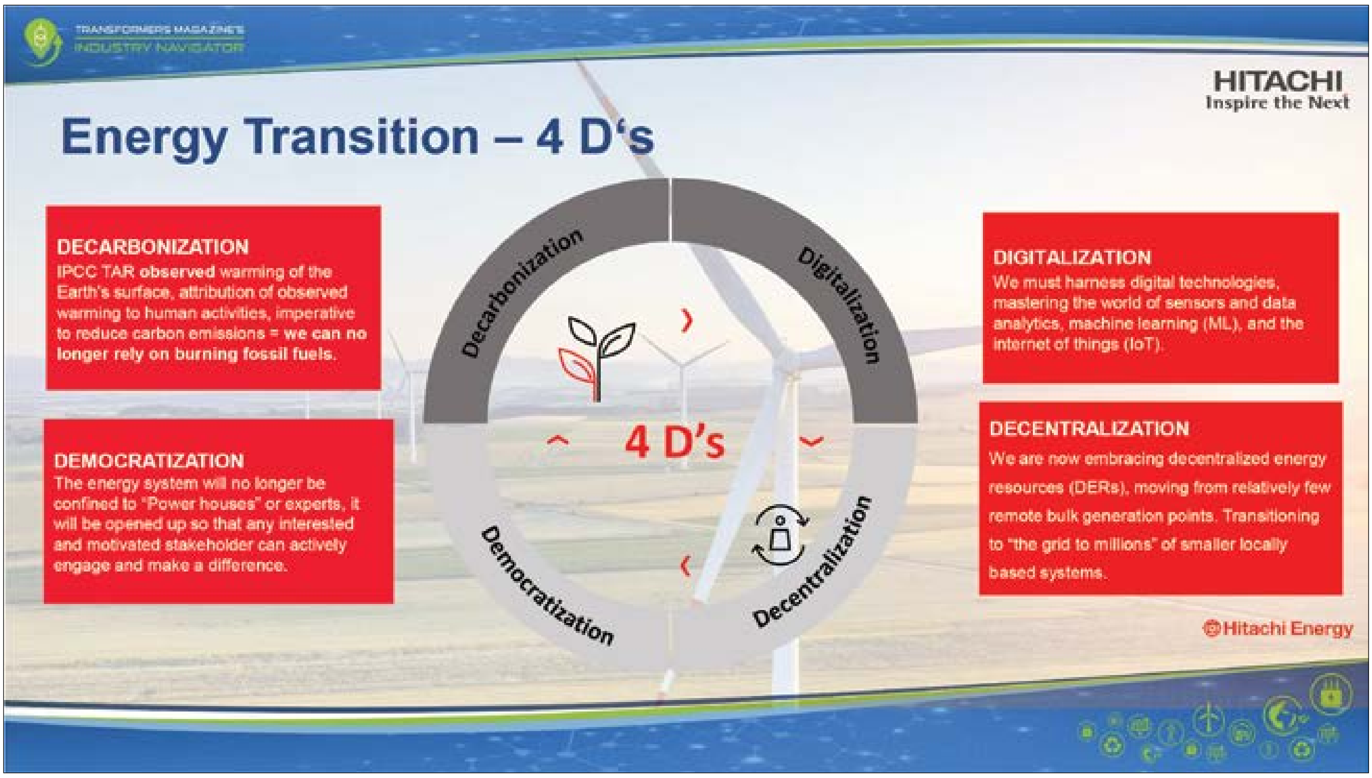

Figure 1. The four Ds of the Energy Transition

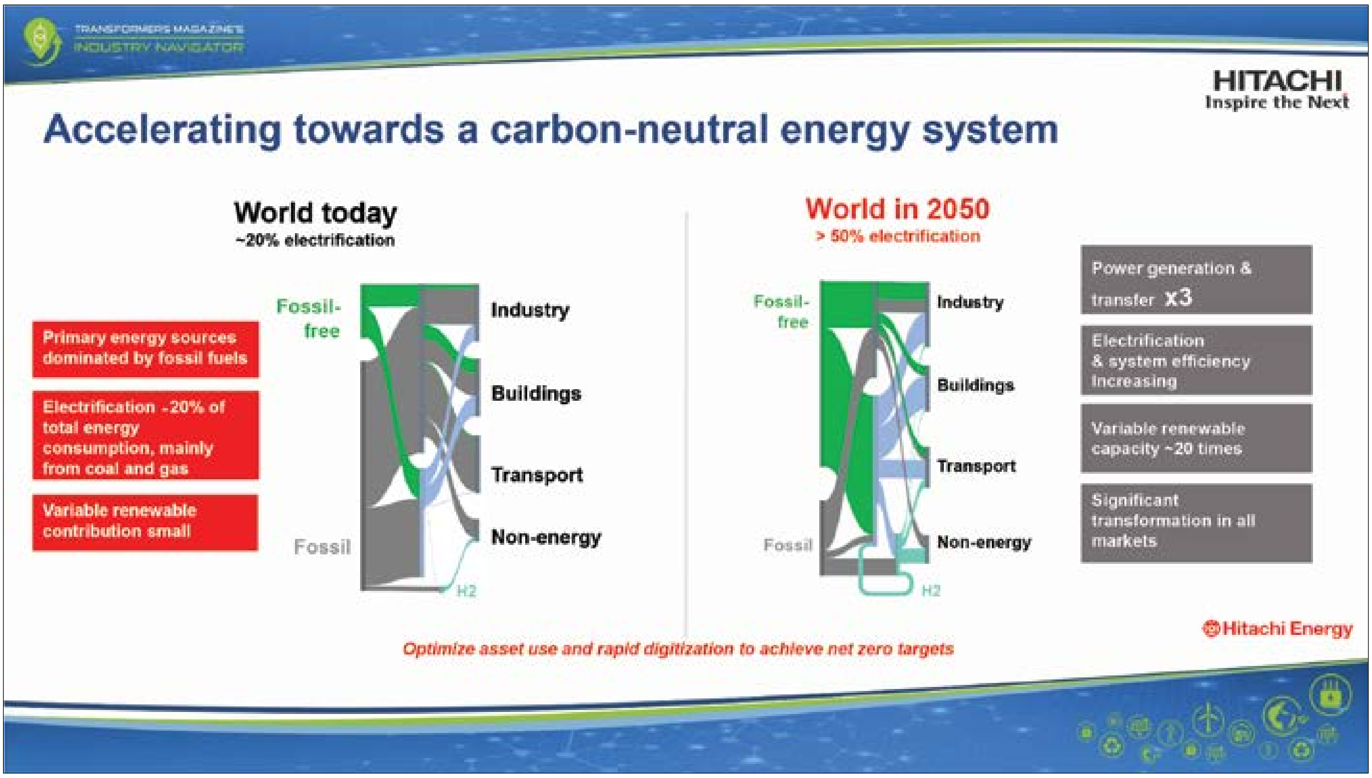

Figure 2. Rapid Digitalisation to Achieve Net Zero

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

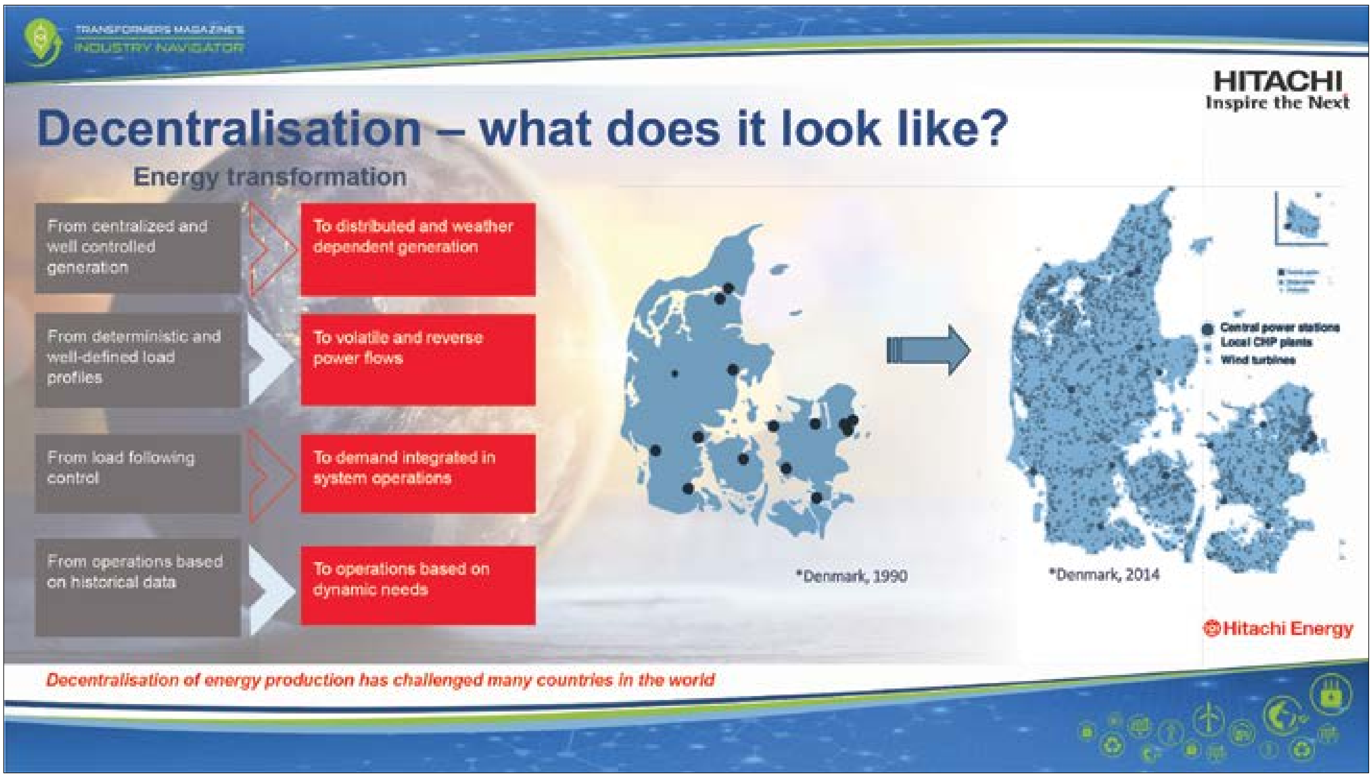

Figure 3. Decentralisation example from Denmark

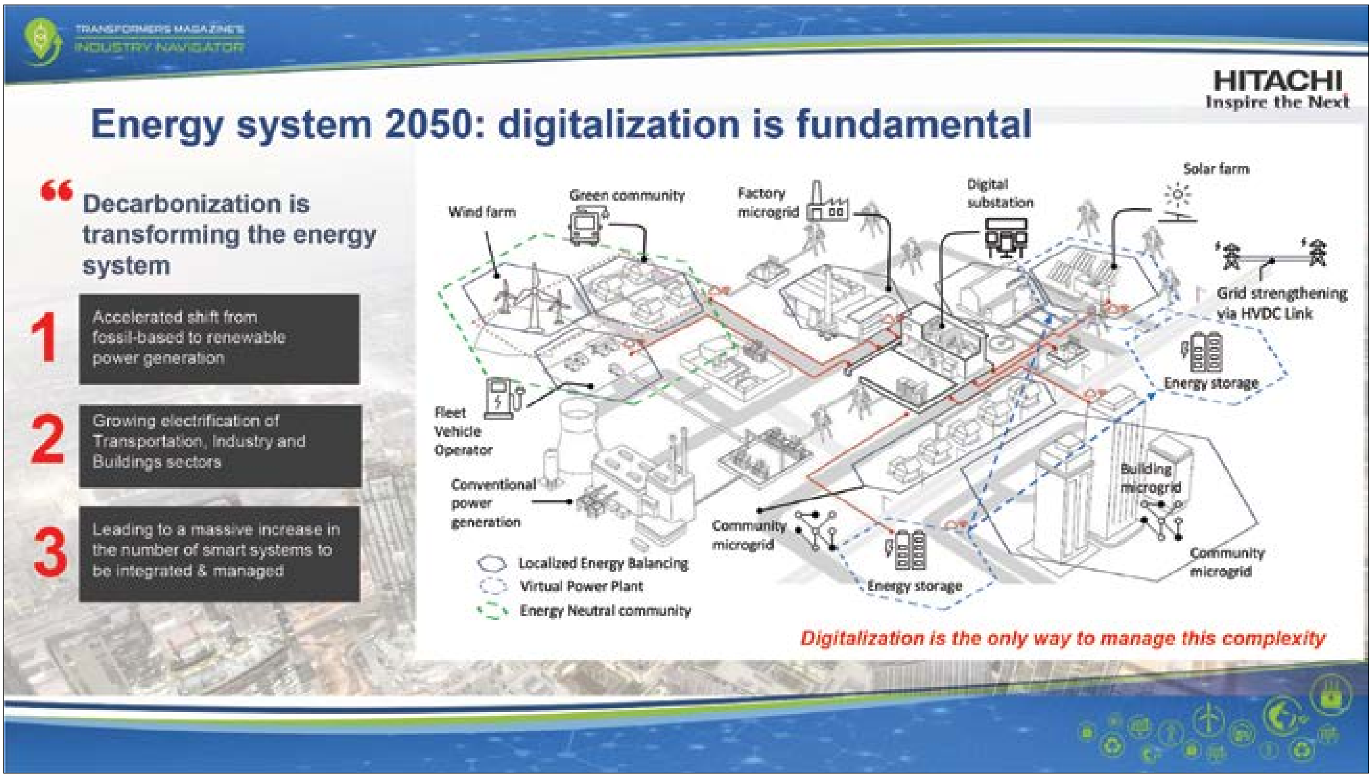

Figure 4. Energy System Vision 2050

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.

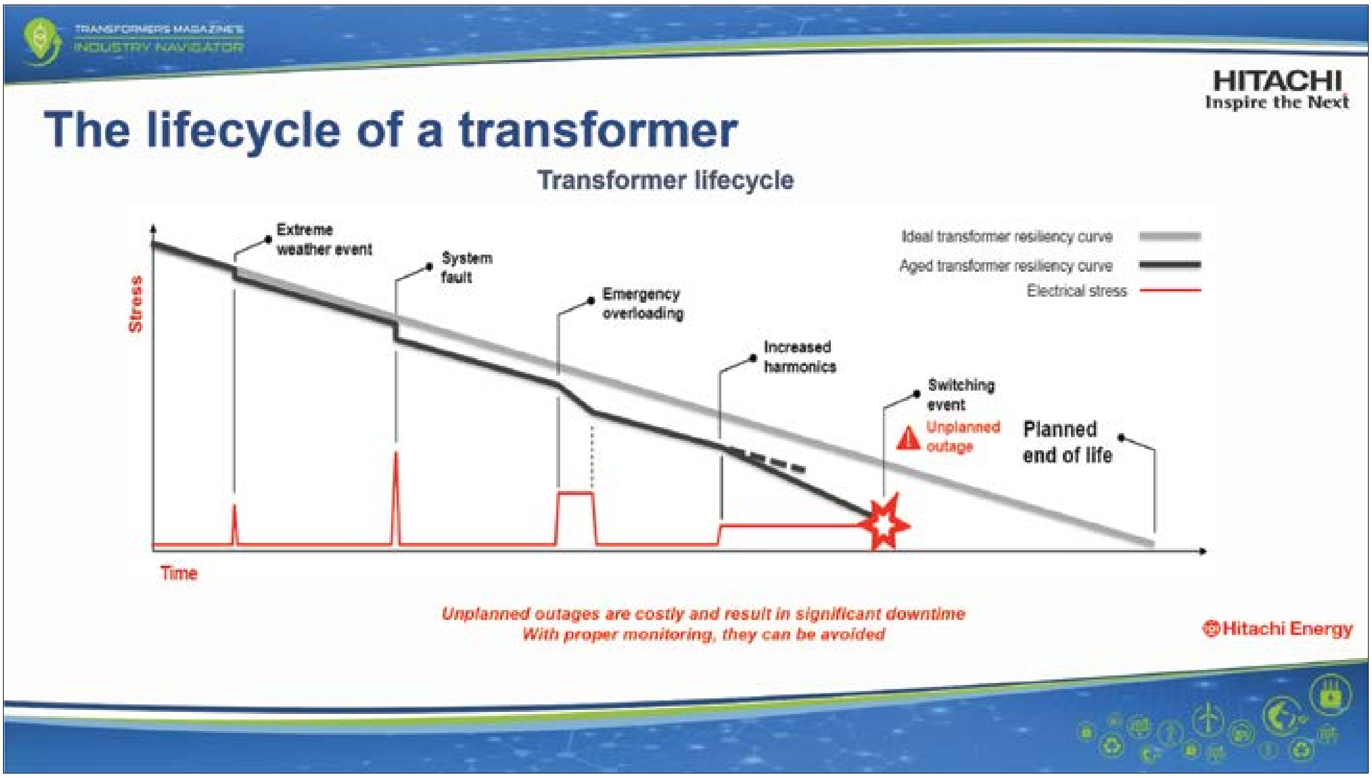

Figure 5. Impact of external events over time

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-

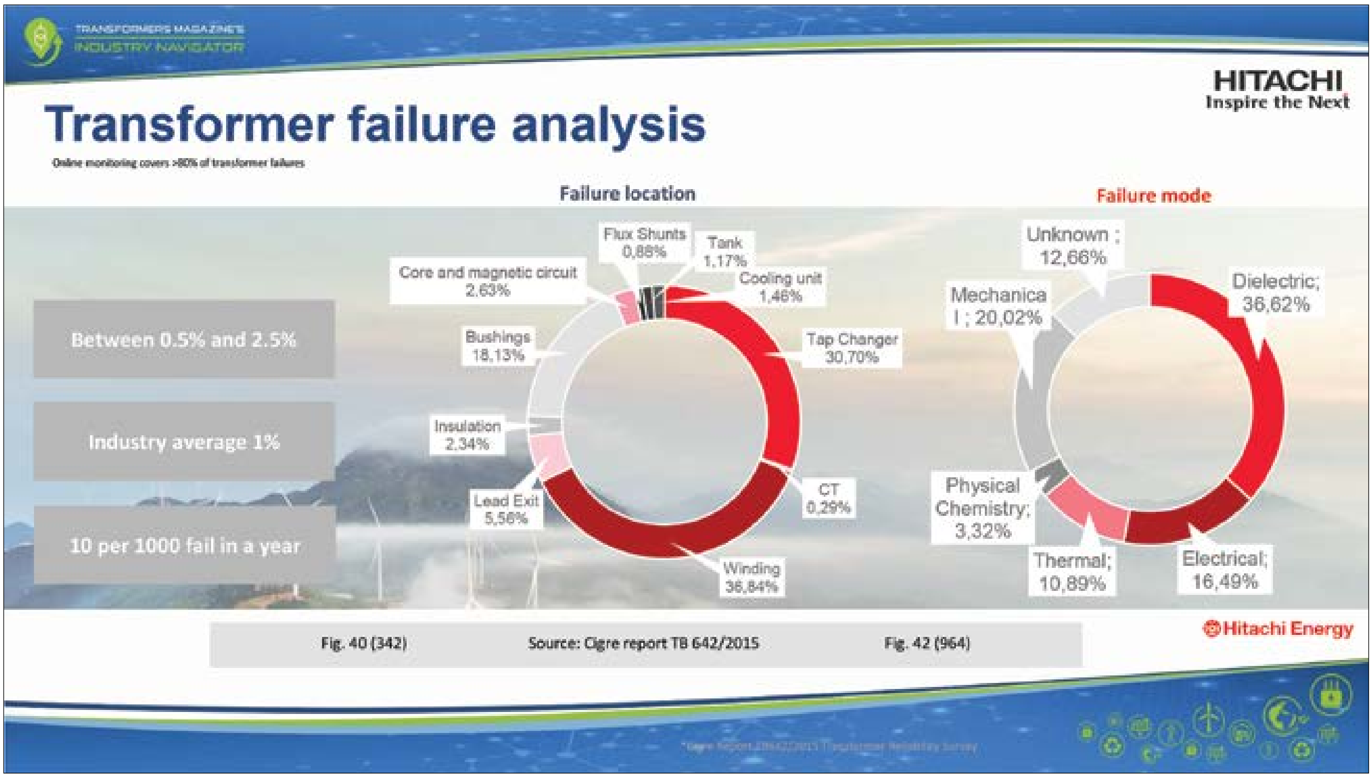

Figure 6. Failure mode and location

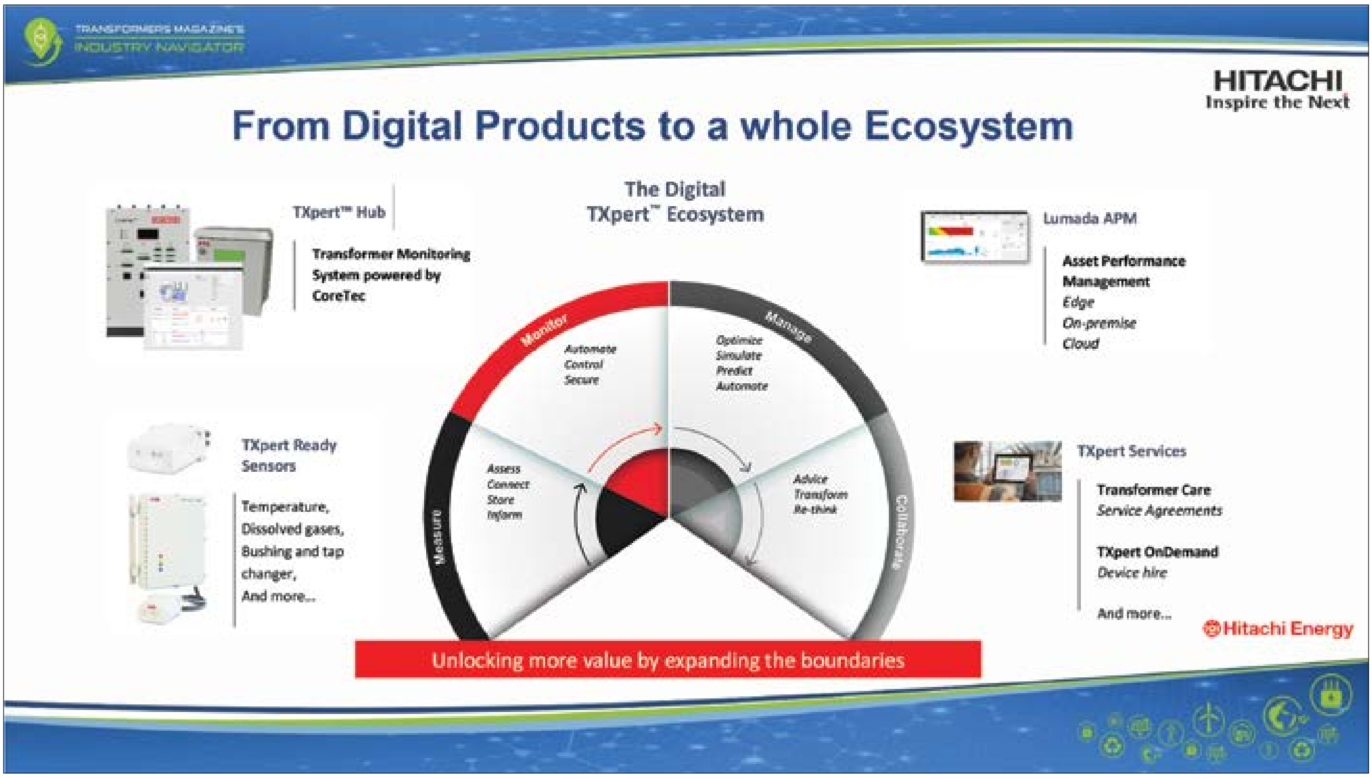

Figure 7. TXpert™ Ecosystem

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-

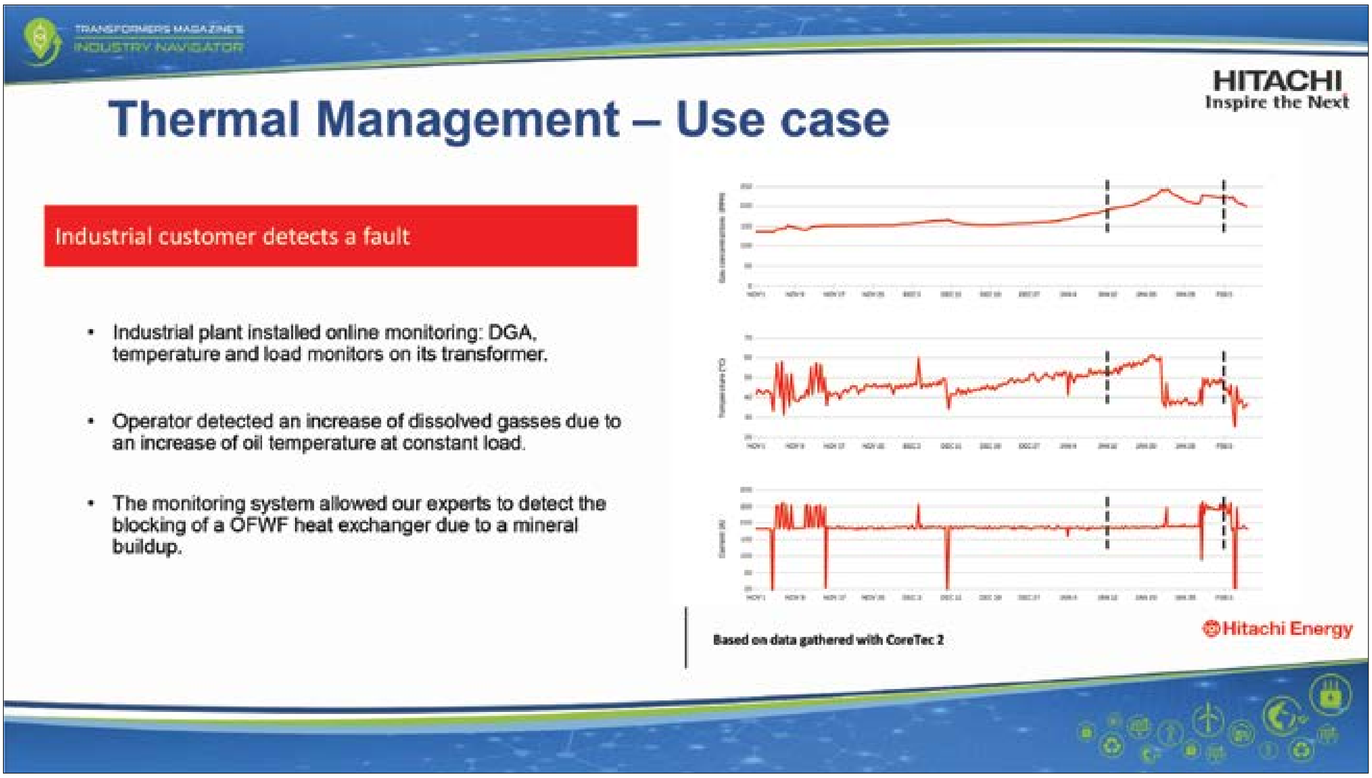

Figure 8. Example illustrating the case of a blocked cooling system.

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

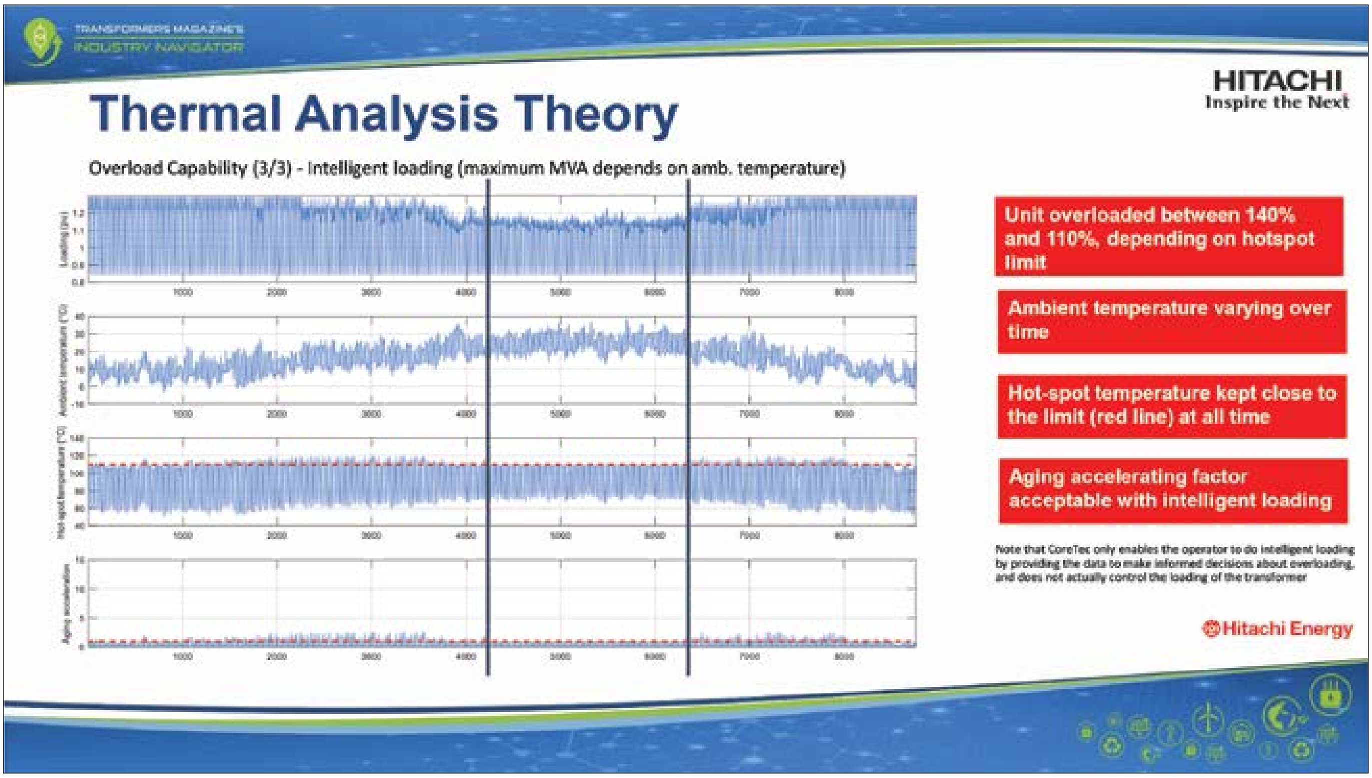

Figure 9. Illustration of hotspot temperature in relation to load and ambient conditions.

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].

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

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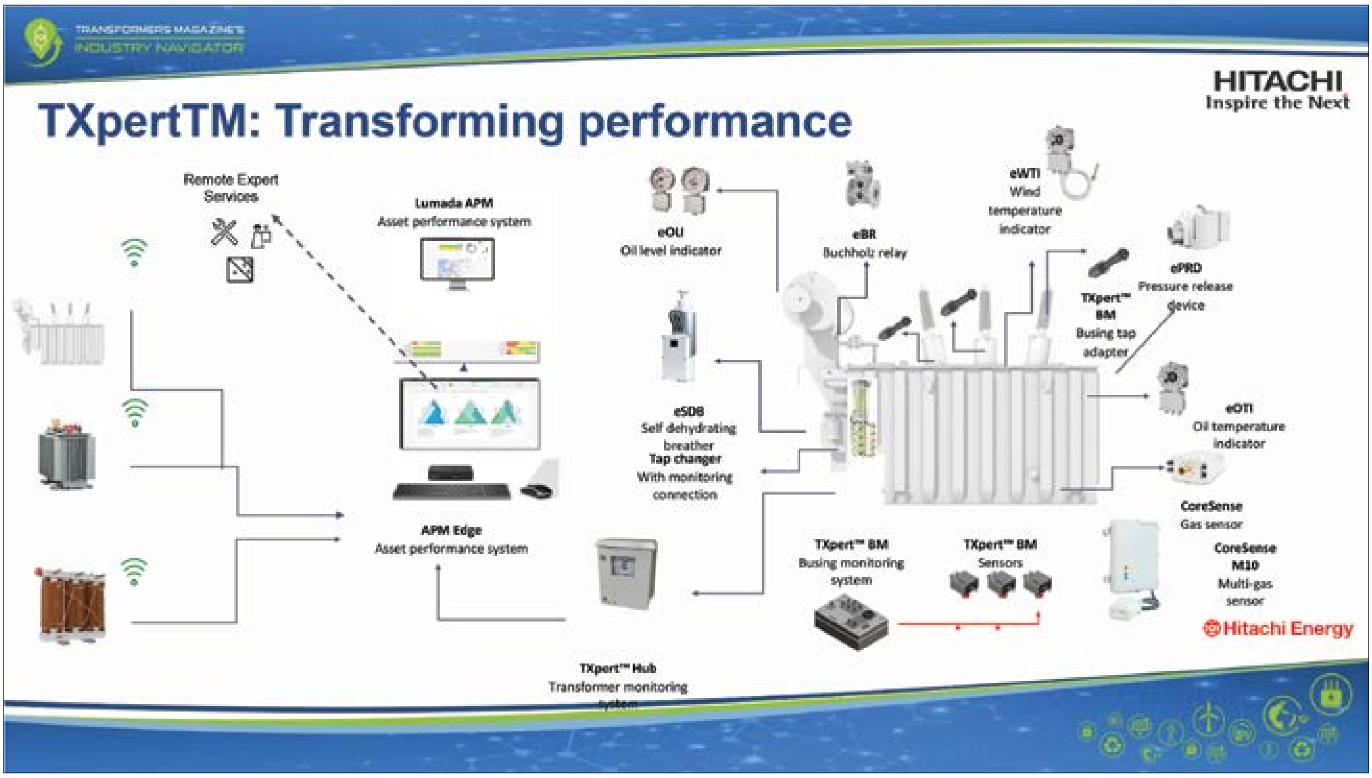

Figure 10. Combination and visualisation of multiple smart sensors

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.

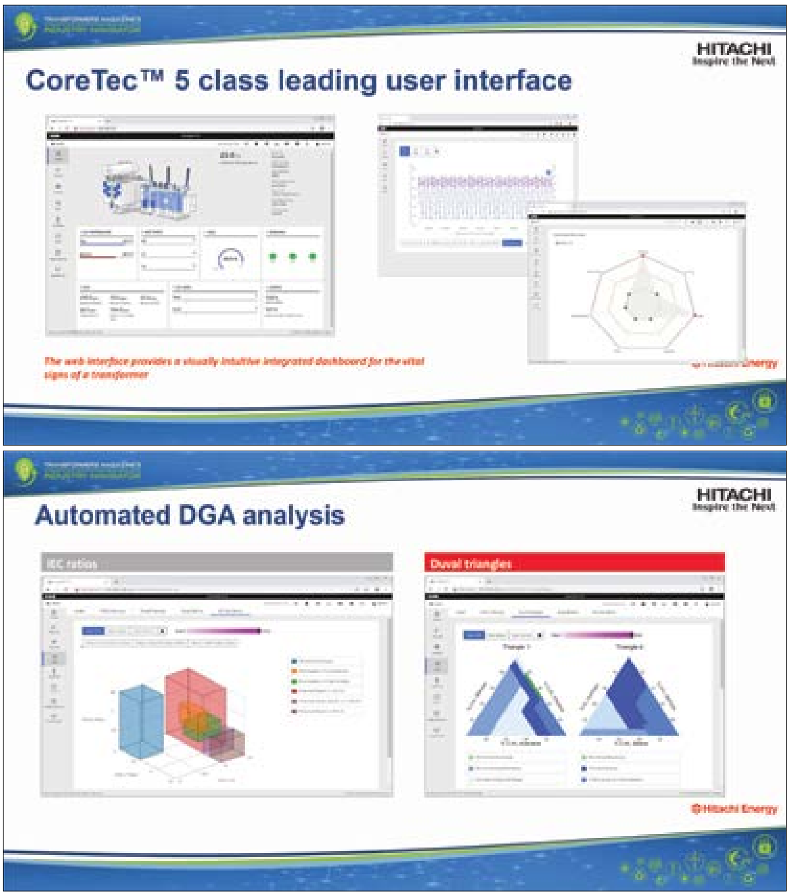

Figure 11. TXpert Hub, application Dashboards.

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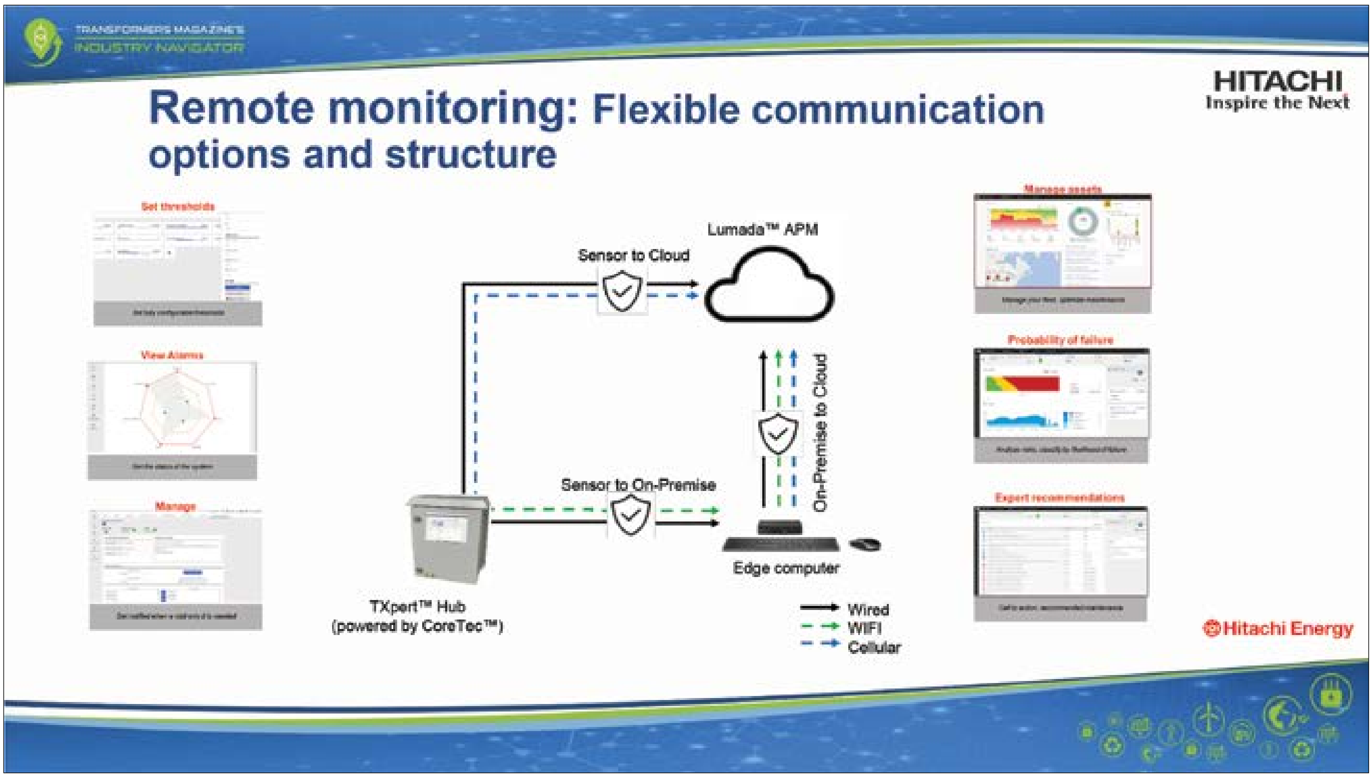

Figure 12. TXpert Hub, local and remote monitoring options

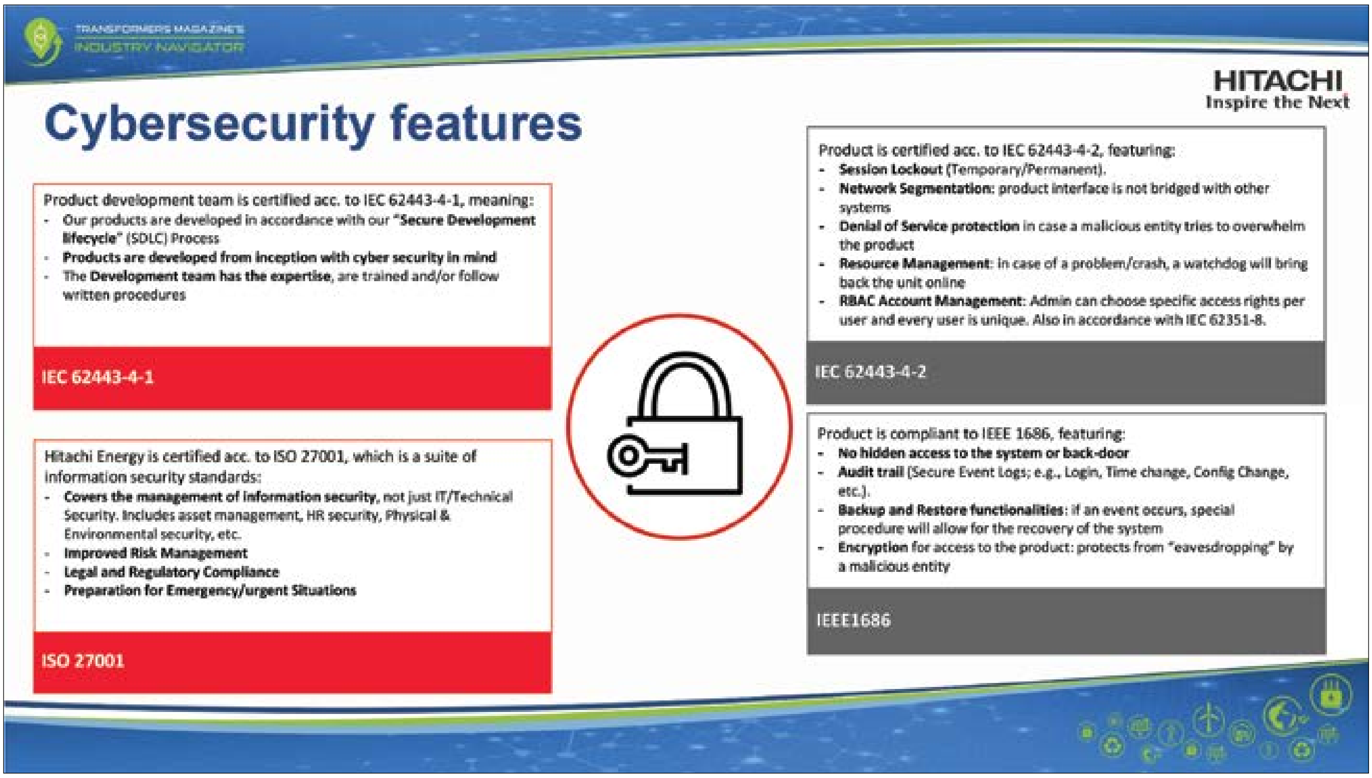

Figure 13. Cyber security considerations

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.