TXpert™ Ecosystem - Transforming performance

Introduction

The key change in benefits from digitalization and trending of transformer parameters relate to the changing nature of the grid. However, the historical elements should not be forgotten. Monitoring was and remains an essential tool to catch any developing faults at the earliest possible stage and prevent potentially catastrophic consequences. While less common than in the past, there can still be some infant mortality, as illustrated in Fig. 1, and identifying a problem at an early stage can mean the difference between dealing with the problem during a planned outage vs. fire-fighting following a failure.

The electrical power landscape is, however, changing and will continue to change at an accelerated rate, with a recent World Economic Forum study [1] indicating the "Energy landscape" will experience more change in the next 10 years than in the last 100. There are many reasons for this, not least of which is the drive towards lower carbon emissions and mega-trends related to it. Often referred to as the 4D's of Deregulation, Decentralization, Decarbonization, and Digitalization.

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Generation

Starting with the generation, the uptake of Renewable power generation has gained significant momentum in recent years [2], and while traditional technologies such as Hydro still have their place, Distributed Energy Resources (DERs) such as wind and solar are seeing the highest growth rates.

The impacts of Distributed Energy Resources are both technical and commercial. From a commercial perspective, the cost of equipment has reduced dramatically over the last 5 years, while scale and experience have grown. This, combined with what could be much shorter approval times than "traditional" generation sources and fast construction / installation times, make even Utility-scale installations increasingly attractive and more common.

The technical impact of Distributed Energy Resources relates firstly to the intermittent nature of the generation levels and secondly to the ever-increasing volume of semiconductor devices connected to the grid and the potential for harmonics. For the purpose of this paper, we will focus on the variable (or volatile) nature of the generation levels, but we recommend those involved at the distribution level also to consider the harmonic impact [3].

Renewables include sources such as Hydro generation, where the generation levels and power flows are, for the most part, fully under human control, solar and in many cases wind generation are classified as Variable Renewable Energy sources (VREs). These are generation sources where only limited control can be applied, and nature still plays a significant part in dictating the level of power available for dispatch. Therefore, these sources can be subject to dynamic changes in many installations. There can also be cases where the timing of the generation is "out of step" with the demand. This can further impact the already known demand variable pre-

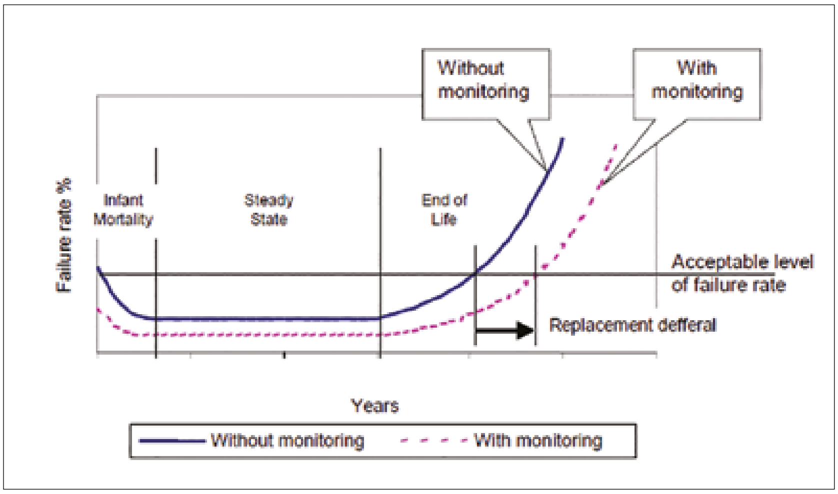

Figure 1. Bathtub curve, with and without monitoring

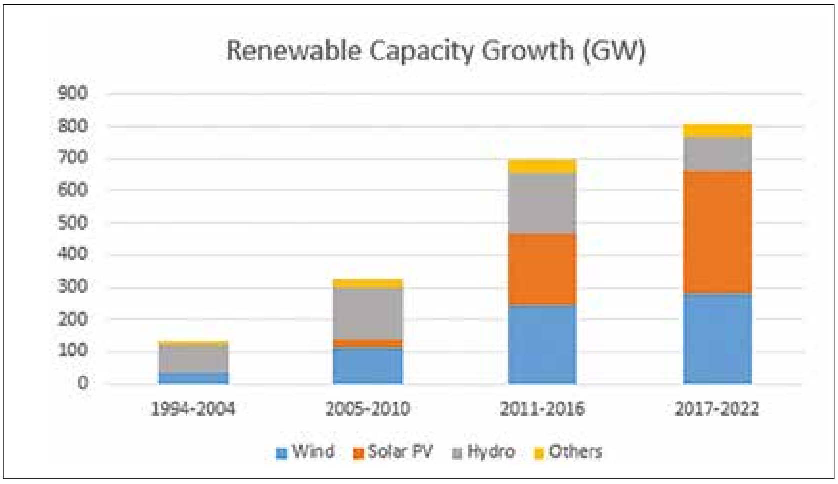

Figure 2. Renewable capacity growth [2]

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viously identified by the California Independent System Operator CAISO, often referred to as the "duck curve," an example of which can be found in Fig. 4.

The impact of the above mentioned DERs is further complicated by the incentives for producers to reduce the traditionally stable generation sources such as coal and / or nuclear. The net impact of the above is an increase in VREs, while at the same time, the grid inertia is negatively impacted by a reduction in stable bulk sources. The impact and timing of some DERs generation are already making their presence felt at the transmission level, with several transmission system operators (TSOs) reporting "over-fluxing" of transformers where the load-side voltage becomes a feed and can even exceed the design parameters of the transformer! In the case of "early adopters," such as California and Denmark, they have invested in strong ties with neighboring systems [4].

Overexcitation is already a major concern for transformers directly connected to traditional generation sources, and although the step-down transformer may benefit from their protection relays in some cases [5], this is not always the case. Presently, it is not uncommon for customers to include core temperature measurements via fiber optics in some specifications, and it is recommended to review tapping range requirements for any transformer that could be subject to "prosumer" type applications [6].

We are already seeing changes in the generation mix, which in turn affects the ways in which key assets such as transformers are being used, and the true impact of these changes can only be seen by monitoring the trends and relationships of key parameters. The TXpert Ecosystem is uniquely well placed to provide such insight into new trends and adapt to changing needs.

Demand

In many countries, demand is still increasing in some regions due to population growth and in others due to increased urbanization and demand per capita. As is the case with the generation, a part of this increase in electricity demand relates to the shift to "clean energy," and the use of electronically controlled devices such as air conditioning, refrigerators, and washing machines is also playing a part. This increase will, however, pale into insignificance if the demand side is impacted, as expected, by the rise in e-mobility and adoption of electric vehicle (EVs) charging. Several countries have already committed to significantly reducing the number of fossil fuel vehicles, and some have gone so far as to set hard targets to prohibit the sales of vehicles that are not electrically powered. With some large car manufacturers forecasting over 25 % of new vehicles to be electrified by 2025 and 80 % of municipal bus fleets to be electric by 2040 [7], the impact of charging networks is already a cause of concern for many network operators.

The uptake of Renewable power generation has gained significant momentum in recent years, which is changing the power grid towards the Distributive Energy Generation paradigm

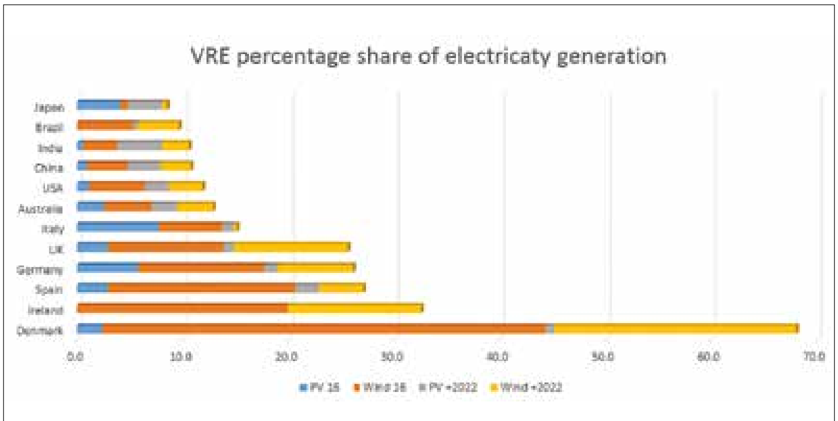

Figure 3. VRE share of generation [2] – Selected countries 2016 to 2022

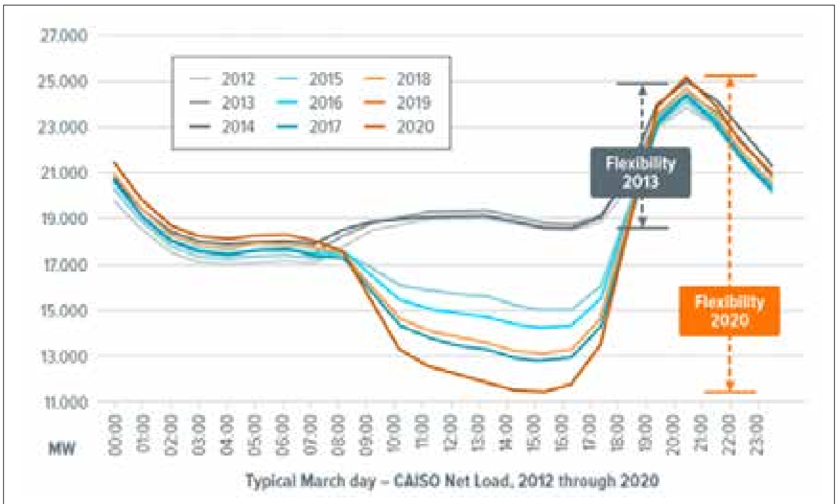

Figure 4. CAISO duck curve example [4]

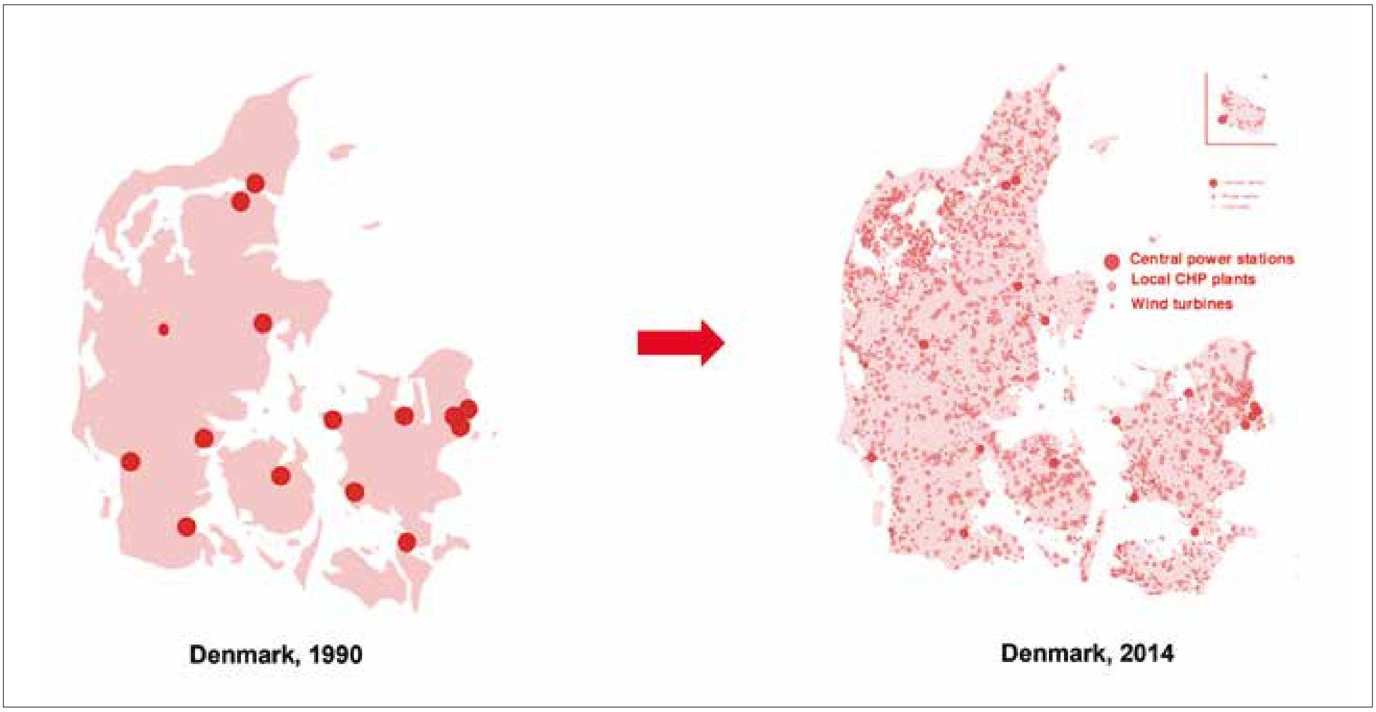

Figure 5. Change from bulk to distributed generation

Sticking with the demand side, data centers are becoming increasingly important for society. These are also more power-hungry than most people realize, and it is not uncommon for individual sites to require as much power as a village or small town. In summary, both the supply and demand side are already more dynamic than only a few short years ago. There is every reason to believe that these trends will only increase and that this will have an impact on how transformers are being loaded, the implications, and the need for operators to better understand how these key assets can be best utilized and maintained.

The TXpert Ecosystem is uniquely well placed to provide monitoring solutions that address the new trends and can easily adapt to changing needs

Natural disturbances

As described above, there are many things humanity can now control. However, this does not yet include nature. The power infrastructure is often taken for granted, but nature has a habit of reminding us of its own raw power, whether through earthquakes or weather "events" such as superstorm Sandy. In a single year alone, there were 16 weather events and climate-related disasters in the United States, with loss-

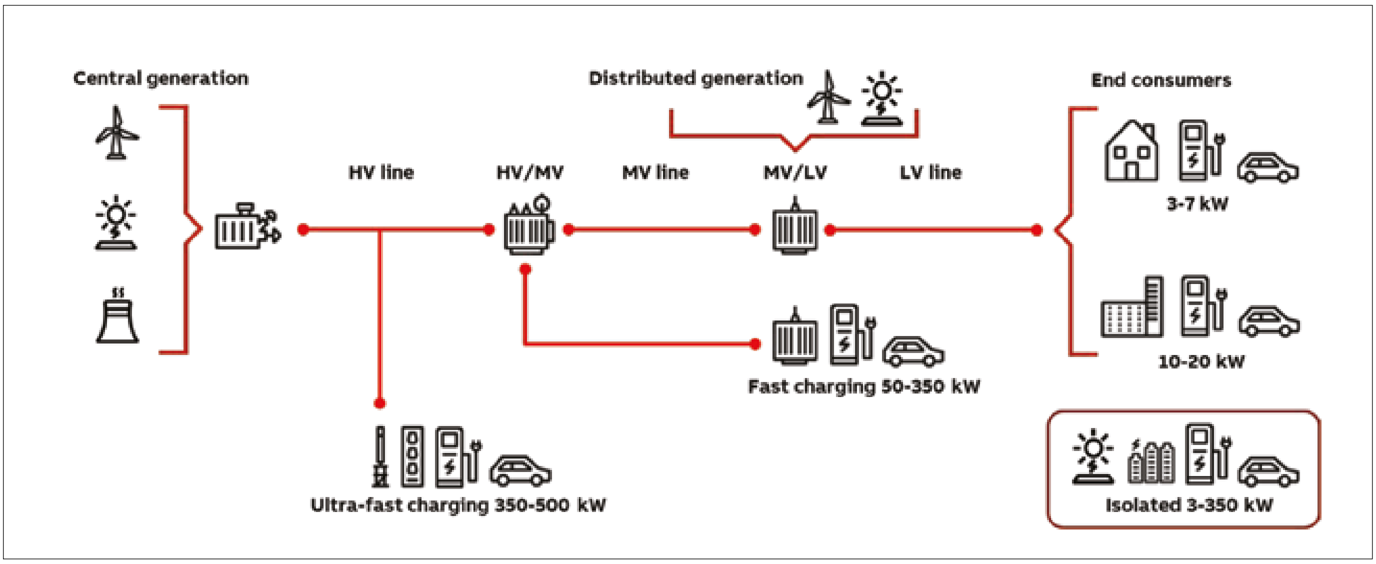

Figure 6. Changing power system requirements

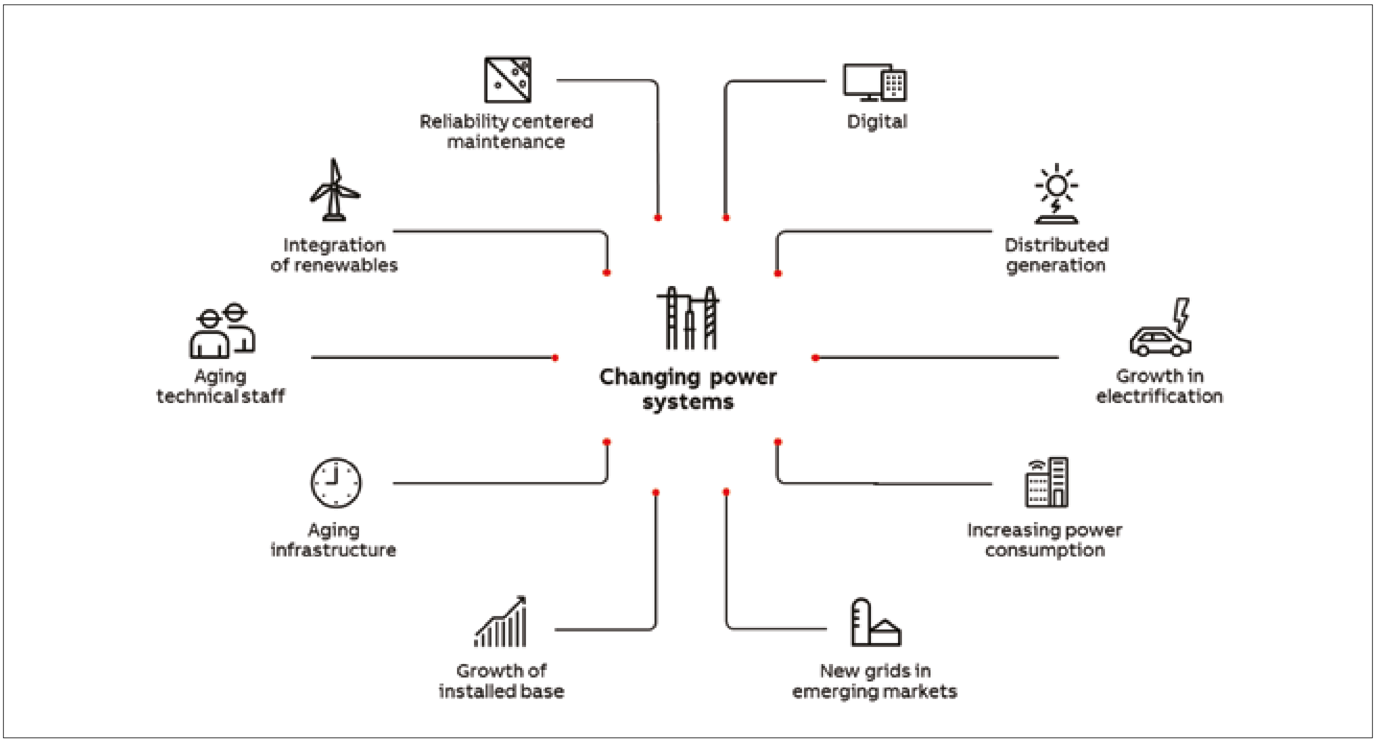

Figure 7. – Changing grid dynamic and business drivers

In a single year alone, there were 16 weather events and climate-related disasters in the United States, with losses exceeding $1 billion each!

es exceeding $1 billion each! According to research [8], 92 % of US organizations have experienced an energy failure in recent years, and over a quarter admit that not having available options is a roadblock to future-proofing their business.

While it is not always possible to prevent damage to key assets, visibility of the asset status and trends prior to any problems is key to forming a cohesive plan on where to focus efforts and resources when re-establishing power. Good visibility is also required when advising customers / consumers of both the status and expectations for when power or production will be resumed.

Outlook

The outlook for operators of power system assets, such as transformers, seems to be driven by increased pressure on the

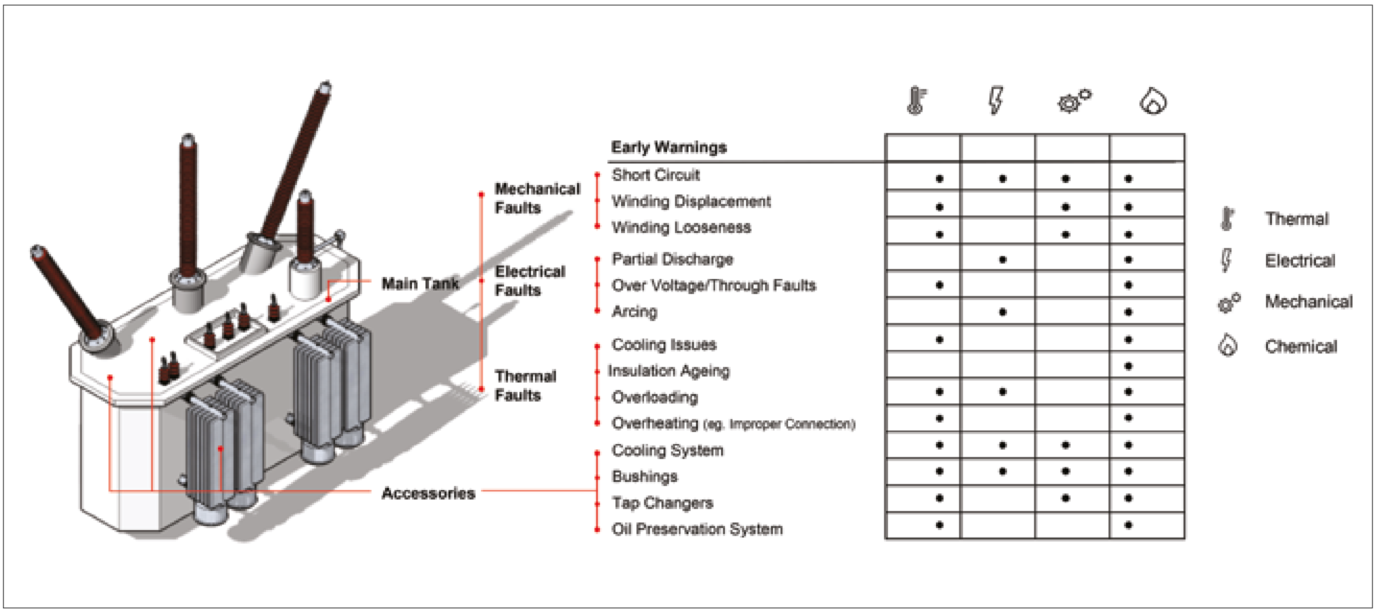

Figure 8. Transformer early warning indicators

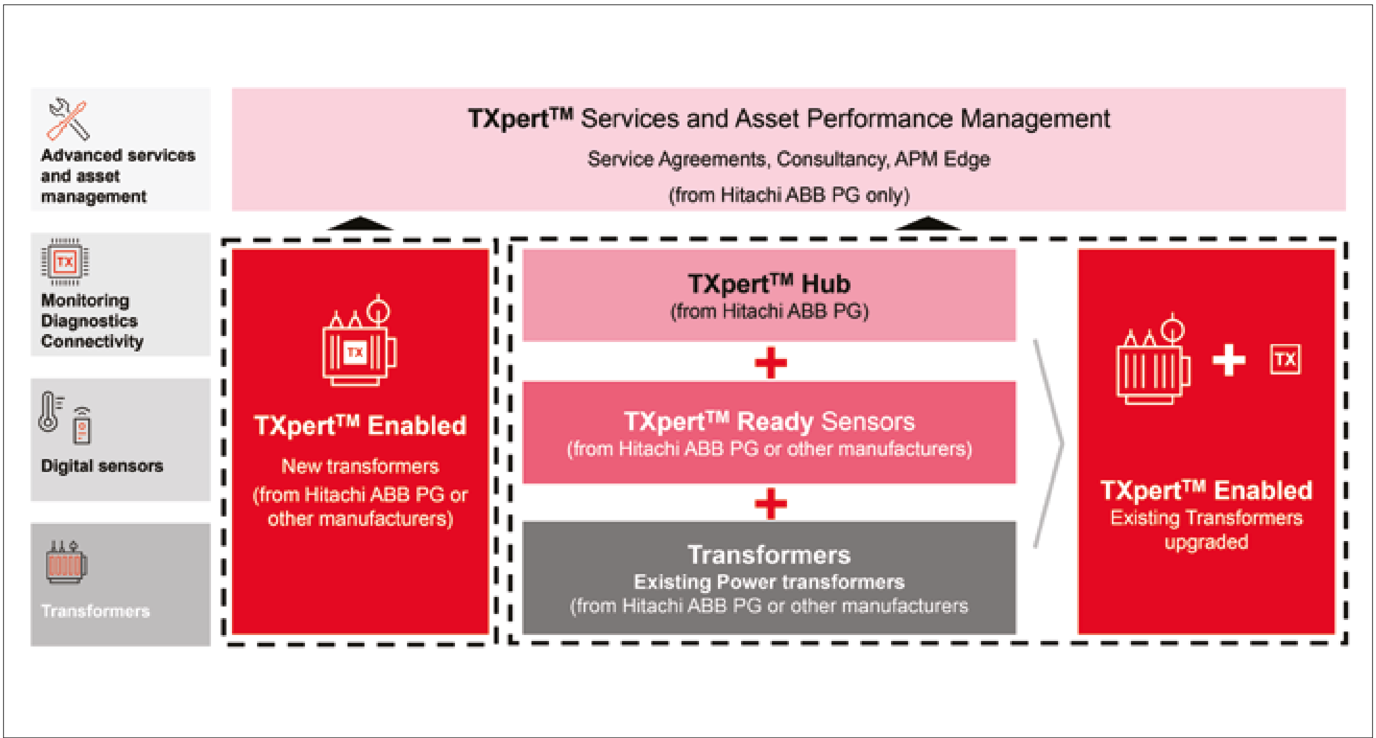

Figure 9. TXpert™ Ecosystem component parts

demands for flexibility, reliability, and profitability, all of which include increased pressure to reduce costs and increase efficiency in both power distribution and relevant maintenance operations. This is all happening at a time when organizations are increasingly faced with gaps in their workforce and difficulties to replace those with the most experienced, many of whom are now of retirement age.

The grid dynamic is set to increase, and the expectation is that more "un-regulated" generation sources and bi-directional power flows will need to be accommodated. In the age of a knowledge-based economy, it is vital the technology offers solutions that provide the ability to visualize what is happening with key assets.

Impact on transformers

Transformers have few moving parts, or at least they should be the case when things are operating as planned. The moving parts they do have, i.e., tap changers and pumps or fans, are typically periodically maintained based on historical timing guidance, which does not include changing load profiles, increased switching requirements, or the impact of external events. There are, however, numerous means through which it is possible to gain insight into what is happening inside thick steel transformer tanks.

The goal for operators of power system assets is to increase flexibility, reliability, and profitability of the system, with the minimum costs and with the maximum efficiency

Actionable information, not data

The use of electronic monitoring devices on transformers is not new, but the historical focus has been managing the end of a transformer's life with standalone devices. This was achieved by customer partnering and building experience, relationships, spare parts, etc., with whoever offered the best technology fit for the device or application at that point in time. Devices and any data from them were typically stored or utilized in isolation.

Looking forwards, the demands on system management are set to increase. However, typical enterprise systems operate in an IT environment or at best incorporate metering and protection systems, so most will not typically benefit from a mass influx of data points from multiple transformer monitoring devices without significant integration effort. Equally, data sources that are not suitably robust to withstand the environment in which the transformer operates will rather be a liability than a benefit.

In the case of transformers, it is important to take a pragmatic approach to digitalization and first consider what the value of information is, what is already available, and what additional information will be beneficial. It is, therefore, paramount that any monitoring solution can both integrate the preferred devices and technologies (already known to the end-user) while facilitating the combination of additional sensing solutions as needs change or new solutions become available. Just as importantly, these data points should not just add to the "data fog" but must be provided in the form of actionable insights and in a timely manner. The transformer's central collection point or "hub" therefore needs sufficient intelligence and storage to meet "local" or day-to-day demands while working seamlessly with asset management solutions capable of providing broader insight at the sub-station and fleet levels. The TXpert platform is uniquely

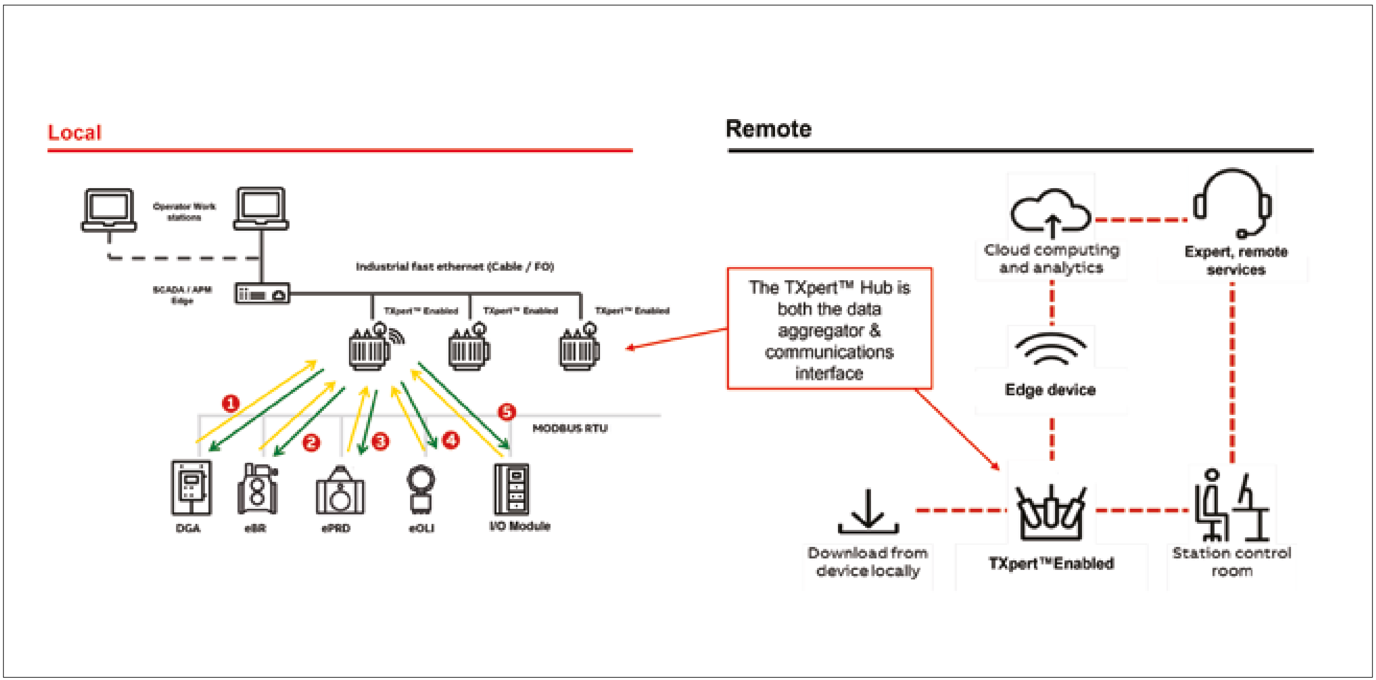

Figure 10. Substation communications

The TXpert™ Ecosystem provides options from total isolation to full integration, and with its vast experience, Hitachi ABB Power Grids can support customers with state-of-the-art cyber-secure solutions

placed to support the integration of customer-preferred technologies into an ecosystem that can add value to customers, either as a standalone device or via easy integration into higher-level systems.

Connectivity

Connectivity is something we now take for granted to the point where a loss of telephone signal or internet connection is already considered more than just inconvenient. The perception of connectivity levels and what is considered safe wildly varies from business to business and situation to situation.

Mindful of the threat of cyber-attacks, most organizations have established policies regarding what devices can be connected to which parts of their IT or OT infrastructure. It is therefore essential that each monitoring solution is not only secure but has the ability to locally store and trend data and retain flexibility, enabling that such data can be easily provided as "useful information" without the need for customers to connect all assets to a sub-station, their enterprise system or third-party internet-based systems. A common pragmatic approach is to deploy "diode-based" communications where data travels only in one direction, and key assets are remotely monitored rather than remotely controlled. The TXpert™ Ecosystem provides options from total isolation to full integration, and with its vast experience, Hitachi ABB Power Grids can support customers with state-of-the-art cyber-secure solutions.

Summary

While most people will not be surprised to see information, communication, and telecoms at the forefront of the digital adoption curve, many will be surprised to see how advanced utilities already are and to learn that some distribution utilities are already employing teams of data analysts. Sub-station automation is also increasingly the norm, so any device installed on a power transformer today should be considered as a foundation for the future, and even if not initially connected to any other device, this should be planned for some point in the transformer's lifetime.

The power grid dynamics and the demands placed on distribution and power transformers are certain to increase over their lifetime, as will their inclusion in "the internet of things" or the Fourth Industrial Revolution. Any transformer aggregator should be considered a hub and an integral part of a scalable solution rather than a standalone device.

Trending of key variables such as loading and temperature is increasingly important, and this should be a foundation for all operation professionals. However, the benefits of being able to compare assets and key parameters significantly increases with either time (and many man-hours) or the ability to connect multiple assets to a central point. The degree of connectivity will vary from installation to installation and business to business, but advantages can typically be found by simply comparing the dynamic data from sister transformers located in the same sub-station or sub-station to sub-station. Professional asset performance management tools take things to a completely different level, capable of providing prescriptive insights and are now a realistic commercial proposition at the substation level. Mindful of the importance data will play in the future, it is recommended to work with both open communications platforms such as DNP3, Modbus,

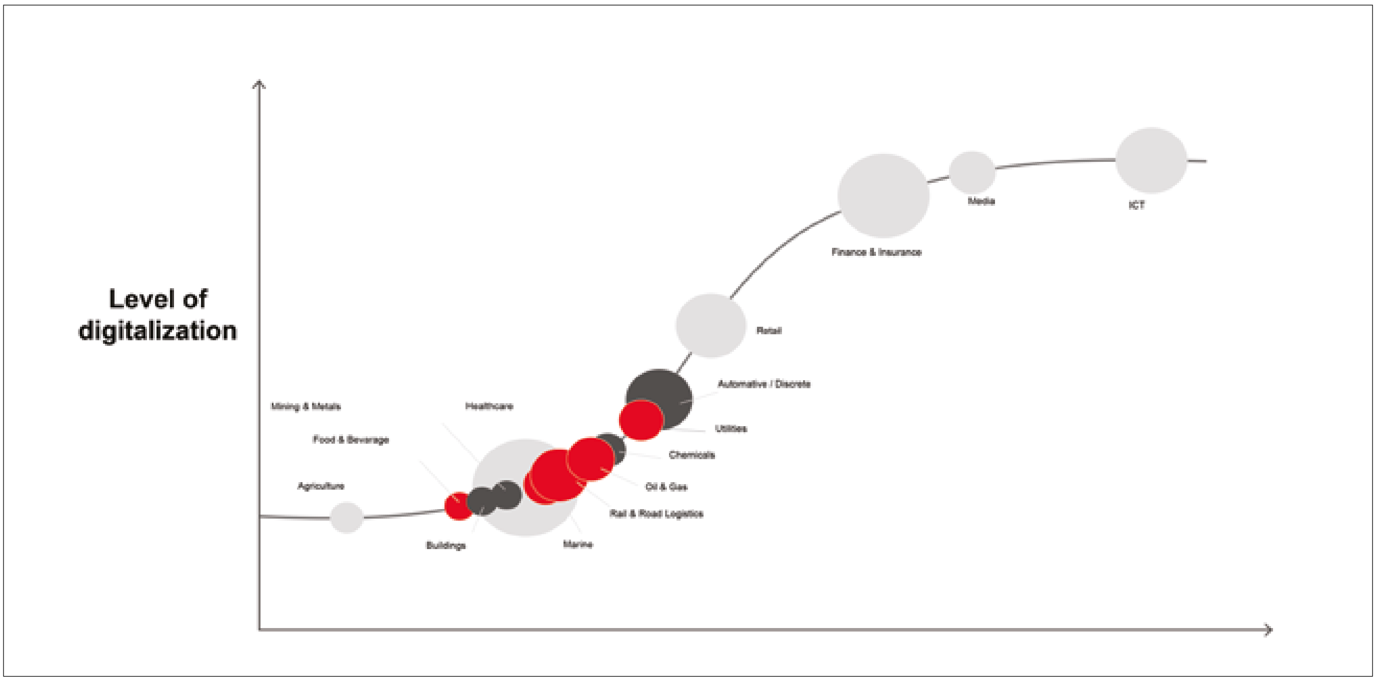

Figure 11. Digital adoption per segment

IEC61850, and asset management tools that can grow with any requirement, which seem set to expand. The TXpert Ecosystem meets or exceeds all the latest cybersecurity requirements and supports all requested industry protocols.

Hitachi ABB Power Grids have combined already highlighted needs with wishes of the world's largest installed base to bring together an open, scalable, manufacturer-agnostic ecosystem for digitalization of transformers, with a complete suite of products, software, services, and solutions. Based on deep domain knowledge, it provides data-driven intelligence for the optimization of transformer and grid operations and maintenance.

The TXpert™ Ecosystem is open, scalable, and manufacturer-agnostic, it provides the foundation for both new and existing transformers to meet the digitalization demands of today, tomorrow and beyond, while simultaneously integrating customer-preferred monitoring devices and providing access to power grid world-leading asset performance management tools, knowledge base, and service network.

The power grid dynamics and the demands placed on distribution and power transformers are certain to increase over their lifetime, as will their inclusion in "the internet of things" or the Fourth Industrial Revolution

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