Smart transformers:

Revolutionizing the renewable energy landscape

ABSTRACT

Most of the installed transformers worldwide consist of conventional transformers, but the global transformer market is expected to move towards smart transformers that are more equipped to accommodate the significant deployment of renewable energy. Smart transformers provide many advantages, including remote monitoring, improved efficiency, and improved functionality. In the future, a range of initiatives are expected to drive the market of smart transformers, especially in the advanced economies (EU member states and the US), including the EU's regulation for power transformers, Smart Grids Task Force, Transformer Resilience, and Advanced Components (TRAC) Program, and Grip Smart Program.

KEYWORDS:

smart transformer; monitoring; efficiency; functionality; energy transition

1. Introduction

Currently, an overwhelming majority of the transformers installed in the world are conventional transformers that allow electrical energy to be transferred between AC power systems at varying voltages but at fixed frequency. The electricity markets across the globe are changing and rapidly moving from conventional generation towards renewable generation in a bid to achieve net neutrality in the long run. This is a direct consequence of the Paris Agreement, a legally binding international climate change treaty adopted by 196 parties at COP21. Paris Agreement aims to limit the increase in global average temperature to well below 2 degrees Celsius compared with pre-industrial levels while making efforts to curtail the temperature increase to 1.5 degrees Celsius compared with pre-industrial levels. [1]

It is noteworthy that renewable energy sources generate electricity at variable voltage and frequency, presenting a comparative challenge for integration into the electricity grid. It is not just a challenging task but has a price tag attached to it. Also, conventional transformers are quite inefficient when it comes to handling either large volumes of electricity or when used for integrating renewable energy into the grid.

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As mentioned earlier, the electricity market across the globe is evolving, with an increasing number of rooftop installations being observed. More consumers are becoming prosumers, generating electricity during the day and consuming it during off-peak hours. This, in turn, requires the ability for bidirectional flow of electricity from the grid to the consumers and from the consumers back to the electricity grid. Smart transformers provide a solution to the problem, as they enable the bidirectional flow of electricity between the consumers and the grid in an efficient manner, whereas a conventional transformer is not capable of doing so in an efficient manner. That is exactly the reason why smart transformers are gaining traction, as they enable the integration of renewable energy into the electricity grid while ensuring that power is utilized in an efficient and cost-effective manner.

2. The advantages of smart transformers

As the electricity market is evolving, it is expected that smart transformers will become far more prevalent, as they provide a range of benefits to the utilities and consumers alike, as opposed to conventional transformers, which are not suited for the modern grid. The advantages of a smart transformer include remote monitoring, improved efficiency, and functionality.

2.1 Remote monitoring

Smart transformer enables remote monitoring, which provides significant value to renewable energy systems, allowing real-time monitoring, data collection, and analysis. This way, system operators are able to detect and diagnose issues in a proper manner, optimize the settings, and improve energy efficiency. Furthermore, remote monitoring helps the utilities identify potential safety issues or malfunctions, which in turn, enables preventive maintenance. As the reliability and efficiency of renewable energy systems improve with the help of remote monitoring, smart transformers contribute towards a sustainable future.

2.2 Improved efficiency

Depending on load demand, smart transformers have the capability to adjust their voltage ratios and other parameters. This, in turn, means that a smart transformer can operate at a higher voltage and a lower voltage without needing manual adjustment while being online. It is significant to note that the voltage ratio of a conventional transformer can also be adjusted, but it requires manual intervention, and the transformer needs to be offline. This ability to automatically adjust voltage ratios reduces energy loss during electricity transmission, consequently increasing the efficiency of the overall system.

2.3 Improved functionality

Smart transformers are equipped with state-of-the-art technologies; for instance, advanced power electronics, digital control, and communication systems, which pave the way for precise control of power and voltage levels, improving efficiency as a result. Additionally, smart transformers can be built with more efficient materials and techniques to reduce losses further and improve performance. For instance, OEMs can use amorphous metal cores with lower magnetic losses than traditional cores.

As the electricity market is evolving, it is expected that smart transformers will become far more prevalent as they provide a range of benefits to utilities and consumers

3. Current trends in the energy market

In order to combat climate change, the global energy market is undergoing a lot of changes as it is moving towards decentralized generation instead of centralized power generation, rolling out renewable energy at a massive scale, and deploying smart grid technologies. Considering the recent trends in the energy market, it is expected that the market for smart transformers will only grow in the future, especially in economies highly inclined towards renewable energy.

3.1 Energy transition

PTR is observing widespread deployment of renewable energy, mainly due to climate concerns driving the global energy transition effort. The feasibility of rooftop solar has pushed the energy market towards deploying decentralized generation assets instead of centralized generation assets, in turn requiring the upgradation of the electricity grid infrastructure. It is expected that the electricity grid of the future will be smart and distributed in nature, with much smaller power plants installed close to the load. This will radically alter the way electricity is produced and consumed in the electricity market. So, in order to make sure that grid infrastructure, especially the transformers, is able to withstand the challenges that follow energy transition, it is mandatory that they have better efficiency, reduced failure rate, and extended lifespan. All of these features are found in smart transformers, which is why it is expected that energy transition will drive growth in the smart transformer market.

3.2 Rollout of renewable energy

According to PTR, around 181 GW of renewable energy capacity (solar and wind) was added globally in 2022. From 2022–2030, global renewable energy capacity is expected to grow at a significant

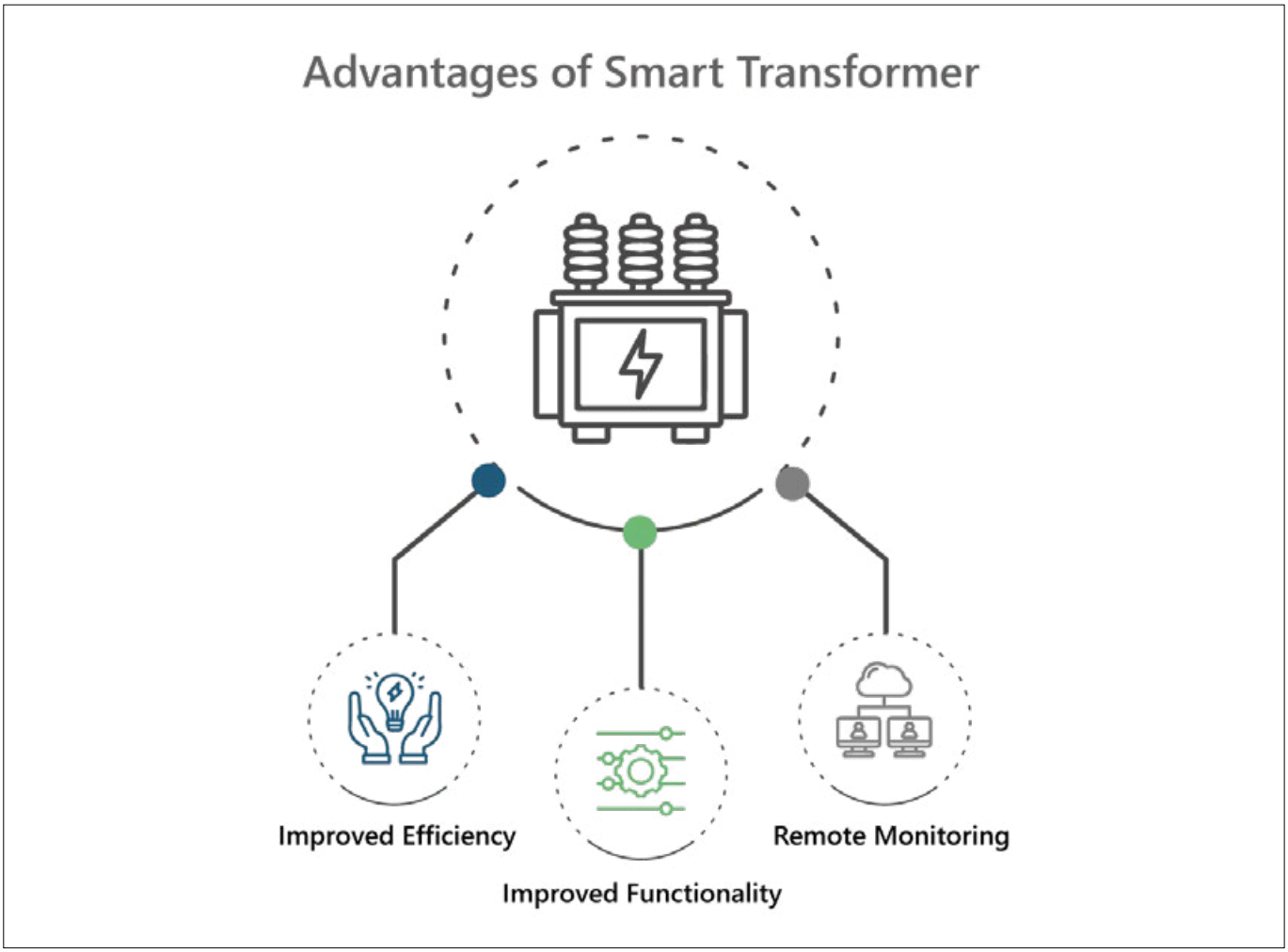

Figure 1: Advantages of smart transformers
Source: PTR Inc.

pace, at a CAGR of 9.5 %. This indicates a marked shift towards non-conventional generation assets; for instance, wind and solar generation, which, in turn, will pave the way for the deployment of smart transformers instead of conventional transformers.

3.3 The advent of smart grids

PTR has observed that electricity grid complexity is rapidly increasing, mainly due to the deployment of distributed generation resources, electric vehicle charging infrastructure, and non-linear loads. In order to cater to the ever-increasing complexity of the grid, a range of technologies is being deployed for electricity in order to make it smart. As the grid undergoes inevitable transformations, it will require the installation of smart transformers instead of conventional transformers. That is why it is expected that, as system operators move towards smart grids, the demand for smart transformers will pick up the pace.

Smart transformers are equipped with state-of-the-art technologies such as advanced power electronics, digital control, and communication systems, resulting in improved efficiency

4. Emerging technology for renewable energy systems

In order to collect data on the performance of the electricity grid and report issues back to the utility or system operator, an emerging technology, IoT, is being integrated into transformers. IoT-based transformers provide insights that help utilities and system operators to remove bottlenecks in the system, thus increasing the reliability of the grid.

Considering the recent trends in the energy market, it is expected that the market for smart transformers will only grow in the future, especially in economies highly inclined towards renewable energy

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Furthermore, it helps the utilities to diagnose potential problems beforehand and schedule repairs, leading to a reduction in operations and maintenance expenses (O&M). That is why smart transformers equipped with IoT are expected to not only increase the efficiency of utilities but reduce their O&M expenditure as well.

5. Policies and programs driving the smart transformer market

Several initiatives in the advanced economies are expected to drive the market for smart transformers, for instance, the EU's regulation for power transformers, Smart Grids Task Force, Transformer Resilience and Advanced Components (TRAC) Program, and the Grip Smart Program in the US.

The EU has passed the regulation establishing eco-design requirements for placing power transformers (with a minimum rating of 1 kVA used in 50 Hz electricity transmission and distribution networks or in industrial areas) on the market or into service to reduce energy waste by 10 %. [2] This regulation does not directly address smart transformers but has set the tone in the transformer market for OEMs supplying to EU member states and utilities to move towards efficient transformers.

Several initiatives in the EU and US are expected to drive the market for smart transformers by providing appropriate regulation, legislation, and policies

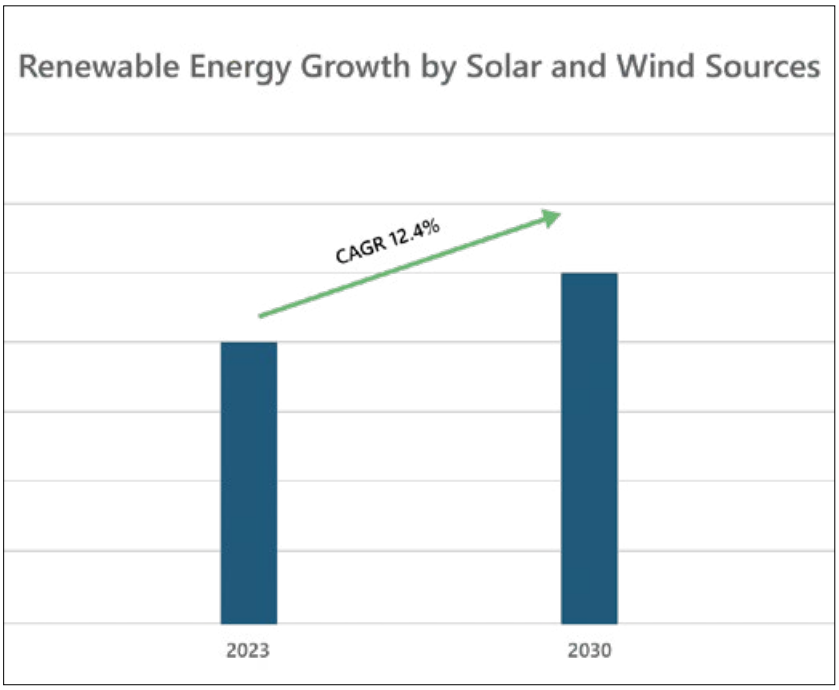

Figure 2: Renewable energy growth by solar and wind sources
Source: PTR Inc.

Smart Grid Task Force in the EU was set up to advise the European Commission on policy and regulatory frameworks at the European Union level in order to coordinate the initial steps toward the implementation of Smart Grids under the provision of the Third Energy Package. [3] This task force assists the Commission in the implementation of present Union legislation, programs, and policies. [3] It provides support to the Commission in the preparation of legislative proposals and policy initiatives. [3] Furthermore, the task force also provides expertise to the Commission when they are preparing for the implementation. [3]

Transformer Resilience and Advanced Components (TRAC) Program in the US supports projects that are focused on creating innovative transformer designs that are more flexible and adaptable in nature, thus enhancing the resilience of the electricity grid infrastructure in the country. [4] This program does not address smart transformers directly as well but is likely to create an ecosystem that, in turn, will create the demand for smart transformers.

Similarly, Grid Resilience and Innovation Partnership (GRIP) Program is a part of the Bipartisan Infrastructure Law, under which funding worth USD 10.5 billion is being provided to increase the flexibility and resilience of the electricity grid, especially in case of extreme weather events due to climate change. [5] The Program offers three funding mechanisms, including Grid Resilience Utility and Industry Grants, worth USD 2.5 billion, Smart Grid Grants, worth USD 3 billion, and the Grid Innovation Program, worth USD 5 billion. [5]

PTR believes that the aforementioned initiatives will be driving the demand for smart transformers, especially in advanced economies, including the US and EU member states.

Conclusion

Globally, the majority of the installed transformer base consists of conventional transformers instead of smart transformers. However, the global transformer market is expected to move towards deploying smart transformers, as they are better equipped to cater to the rising share of renewables in the generation mix compared to conventional transformers.

Smart transformers offer a wide range of advantages, including remote monitoring, improved efficiency, and functionality, making them a popular choice among utility companies and consumers.

As per the estimates of PTR, the installed base of distribution transformers is expected to grow at a CAGR of 5.8 % from 2022–2027. Considering the overall growth projections in the distribution transformer market and the consistent deployment of renewable energy, it can be safely projected that the installed base of smart transformers will also grow significantly in advanced economies. Notably, the situation in the developing economies will be different, as they have a much-reduced fiscal space to deploy renewable energy and support grid infrastructure, including smart transformers.

Power Technology Research believes that the market for smart transformers will be largely driven by initiatives in the future, especially in the advanced economies (EU member states and the US), including the EU's regulation for power transformers, Smart Grids Task Force in the EU, Transformer Resilience and Advanced Components (TRAC) Program, and the Grip Smart Program in the US. It is significant to note that some of the initiatives may not directly address smart transformers but create a kind of ecosystem that, in turn, is expected to create the demand for smart transformers.

The global transformer market is expected to move towards deploying smart transformers, as they are better equipped to cater to the rising share of renewables in the generation mix

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