Globally, replacements of old infrastructure in developed markets and addition of new substations are driving the bushings market

ABSTRACT

Bushings are critical for the safety of power networks. With the power transformer collective market expected to reach around 3.1 billion USD in the European Union over the next ten years, the market for transformer bushings is also developing in parallel. It is expected that the HV bushings market in the EU will reach close to 60 million USD in the same period. Within the EU, Germany is going to be the largest market for the next ten years. Globally, Western Europe remains one of the key markets for bushings, driven by replacements, along with the USA, China, India and Australia.

KEYWORDS

transformer bushings, market overview, future trends, online condition monitoring, porcelain, composite

Power transformer bushings – market trends

A shift towards online monitoring and composite housings

1. Introduction

All generated electricity is channeled through power transformers, and every piece of this equipment is critical for its continuous supply. Overloaded grids in developing countries, aging substation infrastructure in mature markets, and increased renewable penetration are all factors that are causing significantly more stress on grid transformers. This stress leads to failures, which in turn not only cause cas-

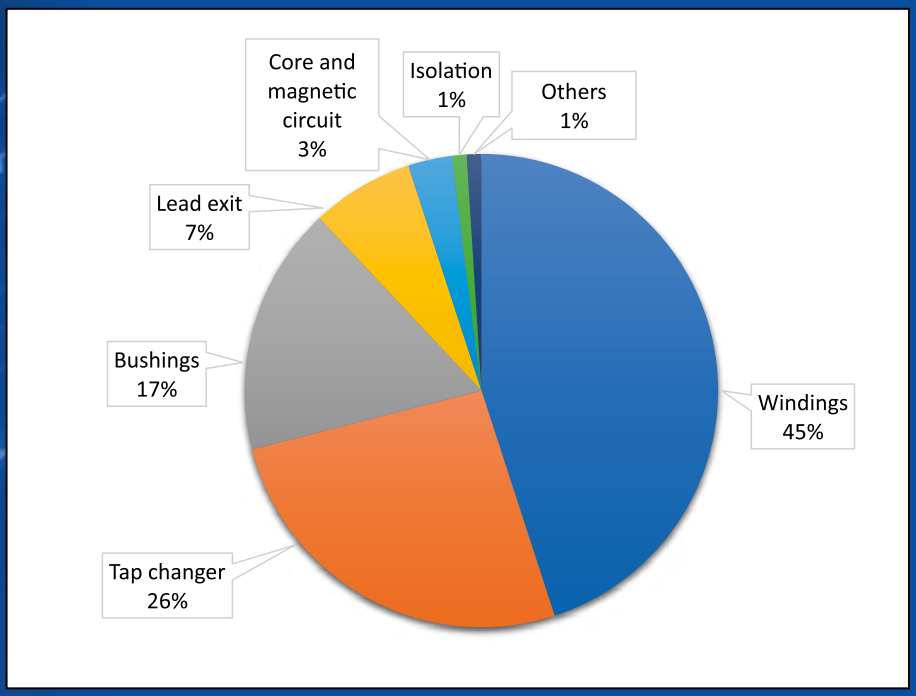

Figure 1. Leading causes of transformer failure [1], [2]

caded blackouts, but also may result in catastrophic events like transformer explosions and fires that can cause casualties.

After windings and tap changers, bushings are the third major point of transformer failure [1, 2]. Nearly 20 % of all power transformer failures located in transmission substations and generator step-up (GSU) applications are caused by bushings. In the transmission grid, transformer bushing failures dominate in high voltage (HV) and extra-high voltage (EHV) transformers (220 kV to 400 kV), as compared to GSU and distribution transformers. The statistics in Europe shows that bushing failures occur between 12 and 20 years after the installation (midlife of a transformer). In 2012, CIGRE conducted a survey (A2.37 Transformer Reliability Survey) [1] which included 56 utilities from 21 countries. The survey concluded that almost 17 % of substation transformers failures are caused by bushings. Additionally, more than 40 % of the total bushings failures resulted in either a fire or explosion incident. All these factors indicate a high risk of bushing failure and its impact on the grid through transformers.

Any equipment playing such a vital role in the electricity infrastructure is expected to be one of the key components stimulating the power equipment market. Globally, an increase in replacement rates of bushings to ensure safety of power transformers is driving the market growth. Many HV and EHV bushings installed in the transmission networks worldwide (especially Europe and North America) are more than 20 years old, which acts as a catalyst for the replacement market. Transformer bushings market variations can be completely different from the transformer markets owing to various factors, including the replacement rates as discussed, but also due to different lead times. In terms of supply and demand, the lead time for power transformers can extend up to 20 months. Since the design of bushings has to be tailored according to specific transformer requirements, bushing lead time can take up to five months [3]. Additionally, trends and transition between composite and porcelain bushings, and solid type and oil-impregnated paper (OIP) type bushings add another layer of complexity to the market. All these factors combined need to be translated into the market sizing and accessibility of transformer bushings.

2. Transformer bushings market assessment

2.1 European market to be driven primarily by replacements

In order to analyze the European transformer bushings market, it is important to understand long-term grid development plan by Transmission System Operators (TSO) in each country. A TSO-based assessment in ten EU countries reveals that the EHV transformer bushings market is driven by replacements in the 400 kV category, while 220 kV market is primarily driven by new additions and then replacements. The estimated annual market volume (in million USD) in the next ten years for 400 kV transformer bushings is depicted in Figure 2. Germany is expected to be the largest market in Europe at more than 8 million USD, followed by Sweden, Belgium and France.

Bushings market can behave completely differently from the transformer market, owing to various factors such as different replacement rates and lead times

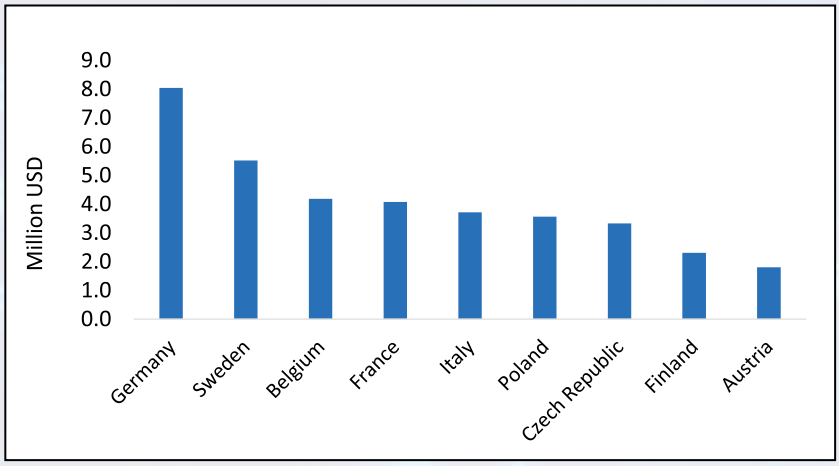

Figure 2. 400 kV bushing market volume 2016-2025 [4]

European EHV transformer bushings market is driven by replacements in the 400 kV category, while 220 kV market is primarily driven by new additions, followed by replacements

In 2015, the Swedish TSO Svenska kraftnät published its ten-year development plan which focused on the reinvestment in its 65-year-old EHV network. This investment is expected to influence EHV bushings with the estimated collective market volume of about 5.5 million USD. Poland is another interesting market in Europe as its TSO, PSE S.A, has announced plans to replace the 25-year-old bushings, which is in accordance with its plans to enhance network reliability. The expected collective market volume for Poland is at 1.8 million USD for 400 kV transformers bushings.

2.2 North American bushings market

The transmission grid in North America is divided into several regional entities, called reliability councils, which are defined by North American Electric Reliability Corporation (NERC). Reliability councils make sure that adequate reliability studies are performed by Transmission Facility Owners (TFOs) to add or replace substation infrastructure for consistent grid operation. NERC's state of reliability report 2017 [5] demonstrates a decrease in outages caused by transformer failures. For 200 kV+ transformers, an average number of outages per transformer has gradually decreased from 0.059 in 2012 to 0.034 in 2016. This annual decline in outages is good news for grid reliability; however, it can result in low replacement market for HV bushings.

A deeper analysis of grid expansion plans from major TFOs reveals that green field additions will still be enough to keep the transformer bushings market at a positive growth rate. Compared to other voltage levels, 500 kV and 345 kV networks are expected to experience most growth in next five years. The annual HV bushings market is expected to be 16 million USD in 2018, with new additions as the main driver of the market [4].

2.3 Australian bushings market

In Australia, around 6 % of the total distribution transformer failures are caused by bushing failures, while in the case of power transformers, the failure rate due to faulty bushings creeps up to 17 %. AusNet, an Australian electricity transmission operator in Victoria, conducted system reliability studies which revealed that transformer bushings installed in Victoria's high voltage network may be a weak link. In last ten years, AusNet has replaced more than 70 transformer bushings and plans to continue the replacement plan in the future as well. From 2004 to 2015, the market volume grew from 0.8 million USD to 1.8 million USD.

Between 2016 and 2021, AusNet plans to replace 220 kV and 500 kV bushings, which will boost the market volume to 2.1 Million USD. From the design point of view, the future market could be influenced by advancements in exterior housing of the bushings and online health monitoring systems.

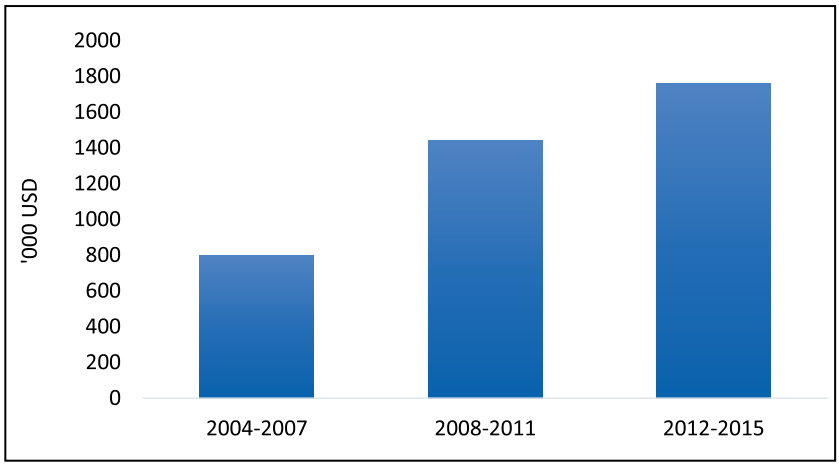

Figure 3. Australia (Victoria State Network) 220 kV bushings replacement [4, 6]

3. Design and technology trends and impact on the market

Composite housing is to see an increase in the market share in the coming years.

The exterior housing material is an essential design criterion which is influenced by ambient conditions. Porcelain and composite are two key material types utilized in the design. Silicon-based composite material is becoming more popular

due to some key advantages over porcelain-based housing. The flexibility and the reduced weight of composite housings is very valuable for safety and ease of handling. Increasing cases of vandalism and terrorism have resulted in a higher use of composite-based exterior for the bushings in order to reduce the risk of exploding porcelain.

In addition, the hydrophobic nature of composite materials, which allows them to withstand harsh environment conditions including heavy rain and dust, has given rise to their popularity over the last ten years as this reduces maintenance costs. Composite housings have also proven to be ideal for bushings under seismic conditions. However, with all these advantages, one strong disadvantage of composite bushings is their higher cost in comparison to porcelain-based housing. At lower voltages, composite housings can cost up to 80 % more than porcelain-based housings, while at higher voltages, the costs are more comparable, with the difference coming up to 20 % based on the design.

Still, because of the advantages of composite housings, specific regions are increasingly preferring composite housings. The European market has shifted from porcelain towards composite at a steady pace and the trend is expected to continue. At present, the market share of composite-based bushings in the European market is around 50 % as compared to porcelain. All urban substations have composite-based bushings in Western European countries. A similar market shift is happening in North America as well, and market analysts expect the market share of composite materials to reach 30 % in five years.

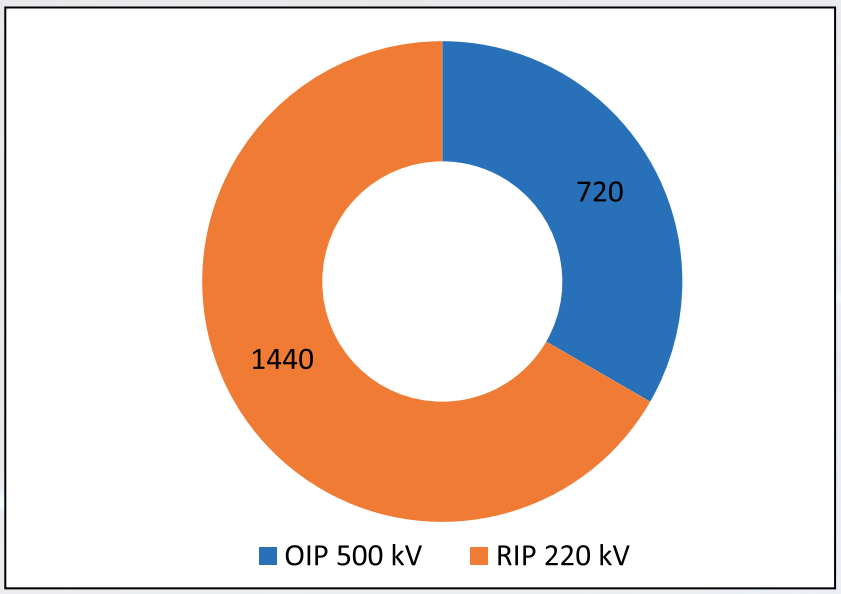

Figure 4. AusNet investment plan for EHV and HV bushings replacement 2016-2021 (000' USD) [4, 6]

4. Online condition monitoring system

As discussed earlier, high voltage bushings are one of the major causes of failures in power transformers, therefore bushings maintenance is of extreme importance. Online condition monitoring for predictive maintenance of critical equipment such as power transformers and gas-insulated switchgears (GIS) has considerably reduced the network failures. However, although recent advancements in online condition monitoring systems have resulted in enhanced performance of equipment, for bushings, periodic offline testing is still the most practiced approach.

Techniques for online condition monitoring of bushings have existed for more than 25 years now; however, we are yet to see its large-scale implementation. Condition monitoring systems for T&D equipment were first developed for critical high voltage systems, with the implementation focus then moving towards less critical systems such as circuit breakers. Transformer bushings market is experiencing a similar trend as the success of condition monitoring systems on the bushings installed in multi-megawatt high voltage direct current (HVDC) projects has started to influence the bushings installed on power transformers. The U.S. market is expected to develop an affinity for online monitoring systems for bushings as more utilities are opting for turnkey asset management systems for power transformers. Additionally, special applications such as wind power step-up transformers require

Composite housing is to see an increase in the market share in the coming years

Table 1. Porcelain vs. composite bushing housing comparison

Feature	Porcelain	Composite
Weight	heavy	90 % lighter
Fragility	highly fragile	flexible
Vandalism	more susceptible	resistant
Hydrophobicity	non-hydrophobic	hydrophobic
Lead time	long	short

Source: Power Technology Research [4]

It is expected that in some markets and in some applications the affinity for online monitoring systems will grow

installation of online health monitoring for bushings. Some typical examples can be found in Northern Germany, where bushings installed on wind GSU transformers went through multiple failure and replacement iterations. This forced the equipment manufacturer to install online bushing monitoring system which helped identify the root cause of bushing failures.

Conclusion

The European market outlook for HV bushings looks strong, experiencing steady growth driven by reinforcements planned by network operators. More specifically, 400 kV bushings market is driven by end-of-life (EOL) replacements, whereas 220 kV market growth is a combination of new additions and replacements. North American market is expected to be driven by green field additions in the network, mainly in 500 kV and 354 kV grid infrastructure. Western European countries have the highest affinity for composite-based bushings; however, this preference for composite material over porcelain is also being emulated in the North American markets.

Currently, there is a rigid mindset in the industry regarding the application of asset management systems on bushings; however, this trend is expected to change as nowadays more utilities are opting for turnkey management solutions for HV transformers than in the past. This inclination towards automated data logging/monitoring system can be even steeper as stricter grid safety standards are introduced by central authorities such as European Network of Transmission System Operators for Electricity (ENTSO-E) and U.S. Department of Energy (DOE).

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Author

Saqib Saeed is an expert in power system design and power electronics components. He has prior experience in commissioning and maintenance of power systems. Since 2015, he has been involved in consulting projects with transmission and distribution (T&D) OEMs and utilities conducting online and offline market research to identify business opportunities for equipment manufacturers like HVDC, FACTS, power transformers and gas insulated substations. His current role of a Principal Analyst at Power Technology Research is to lead critical market research topics and develop coherent methodologies for substation equipment sizing and power electronics areas. Saqib has a Master of Sciences in Power Engineering from Technical University of Munich and a Bachelor of Sciences in Electrical Engineering from University of Engineering and Technology Lahore.