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High Efficient Transformers

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ABSTRACT

Earlier conventional transformers usage in power grids has had a fairly one-sided existence for many decades. An interesting, challenging and promising solution for this is smart grids. Smart grids are more flexible ,intelligent enough to integrate a great amount of renewable energy and energy storage systems, which calls for more flexible and more controllable smart grids. Smart transformer (ST) with power electronics technology has found its application in the power distribution system which executes a significant working role in the forthcoming electrical distribution grid system; deliver many advanced grid services related to the traditional transformer. The solid state transformer advanced functionalities are capable enough to exploit the load dependence on voltage for providing services to the distribution and transmission grids. This paper aims at providing a broad view of comprehensive study of the current status of smart transformers around the world and applications to the researchers and the application engineers dealing with power quality issues.

Keywords*: Integration, power distribution system, renewable energy, smart transformer, solid state transformer*

INTRODUCTION

The significant growth of Indian transformer industry can be seen over the past decades. It may be related to specific design characteristics or properties of transformers tremendous improvement has achieved. Additional demand for transformer technology is emerging because of dynamics in the power market across the world. With rapid growth in the generation, transmission and distribution segments grid complexity has increased. Apart from efficiency, the shorter payback time requirement also influences technical decisions, including design, choice of materials & maintenance strategies etc. Distribution segments are fraught with aging infrastructure, high network losses & poor financial performances. To address these challenges, it is critical to strengthen the performance of sub transmission and distribution networks. Smart Grids are the new watchword. The smartness enhances value for the end consumer by enhanced and convenient availability of electricity. Smart transformers as an integral component part of the smart grid, works independently to constantly regulate voltage, allows remote administration if needed by maintaining contact with the smart grid and to provide information as well as feedback about the power supply by voltage optimization process. Smart transformer is also capable of providing the exact amount of power that is needed, and responds quickly to fluctuations arising within the power grid, it ensures that optimized voltage is not disturbed by acting as voltage regulator. The need, necessity, development of smart grid increases the demand of smart and advanced transformers for power systems.[3]

Need of a Smart Transformer: Today's transformer includes multiple intelligent

electronic devices (IEDs) covering different aspects of the transformer. Monitoring gives access to real-time condition information, even from remote location; it mainly helps the asset owner to monitor the behavior of the transformer core, windings, oil, tap changer and bushings. When changes in conditions are detected, the operator is notified immediately. Monitoring improves the reliability of the assets by continuously observance a watchful eye on the utmost critical transformer components. Dynamic control of real and reactive power can optimize the efficiency of distribution systems, improve power quality in a more dynamic operating environment and limit fault current. Meanwhile, modeling and simulation can be applied to optimize current designs and explore new concepts that can facilitate system recovery in the event of failure. Modularized design components, standardization and recovery concepts can help improve resilience. Smart transformers directly reduce energy consumption. Therefore, it directly reduces greenhouse gas emissions as well. During periods of power fluctuation smart transformers can be administered dynamically and also allow facilities to monitor and manage the transformers directly. Monitoring frequently helps in ensuring that their power supply remains voltage optimized even when new demands are being loaded upon it.

Typical Smart Transformer Hardware Control

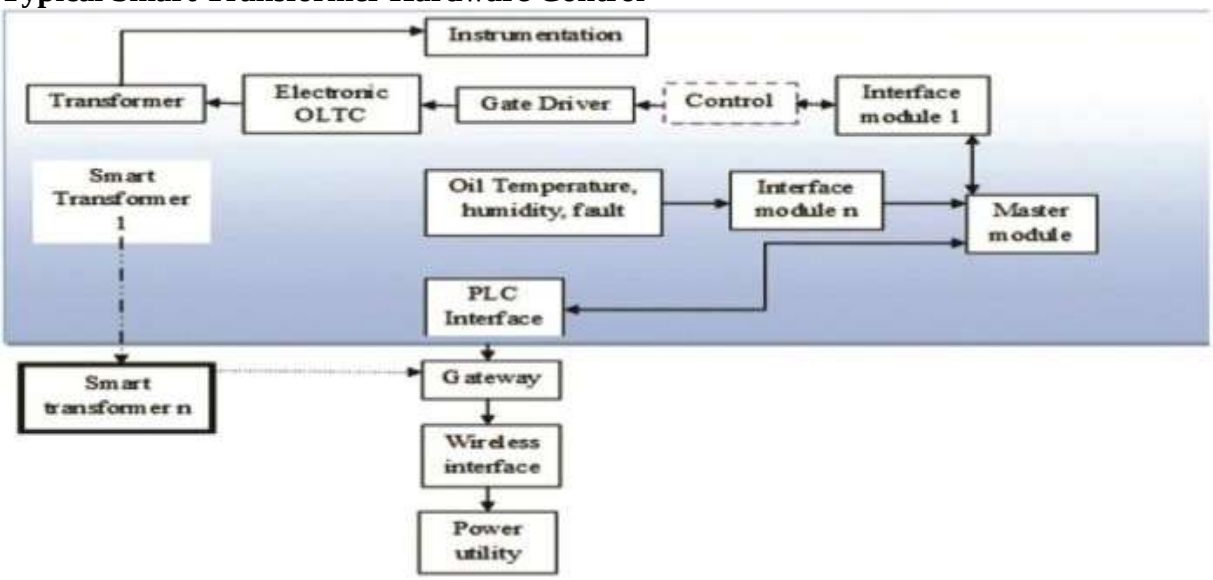

Fig. 1: *A Typical Smart Transformer Hardware Control.*

Hardware control block sets like smart transformers, instrumentation, control gate drives, electronic On Load Tap Changer (OLTC), transformer mostly constructs the voltage regulation block, it's too liable for the secondary voltage regulation.

1. The interface module (i.e. data converter block), converts variables and events of the control system and sends them to the master module.
2. Data of all the interface modules are packed in the Master module and sent to the Programmable Logic Control (PLC) interface.
3. PLC interface converts the data that is to be sent through the medium voltage line.
4. Gateway block receives all the data coming from a set of transformers and sends them to the wireless interface by concentrating it. From this block, the data are sent to the power utility

where it is received and processed.

Depending on the state of both networks(micro grid and utility grid) and other information communicated to the smart transformers helps in Controlling of active power exchanges between the micro grid and utility grid is possible when smart transformers are used at the Point of Common Coupling (PCC). They prove to be powerful components that provide faster and superior voltage regulation, frequency regulation, and regulation of the harmonic behavior of each feeder.

For reducing the core size, isolating different voltage levels, and minimal loss, proper power converter cells have to be chosen after the smart transformers are chosen for use because the Power converter cells are the basic blocks of these transformers.

The basic structure of the above design is shown in Figure 2

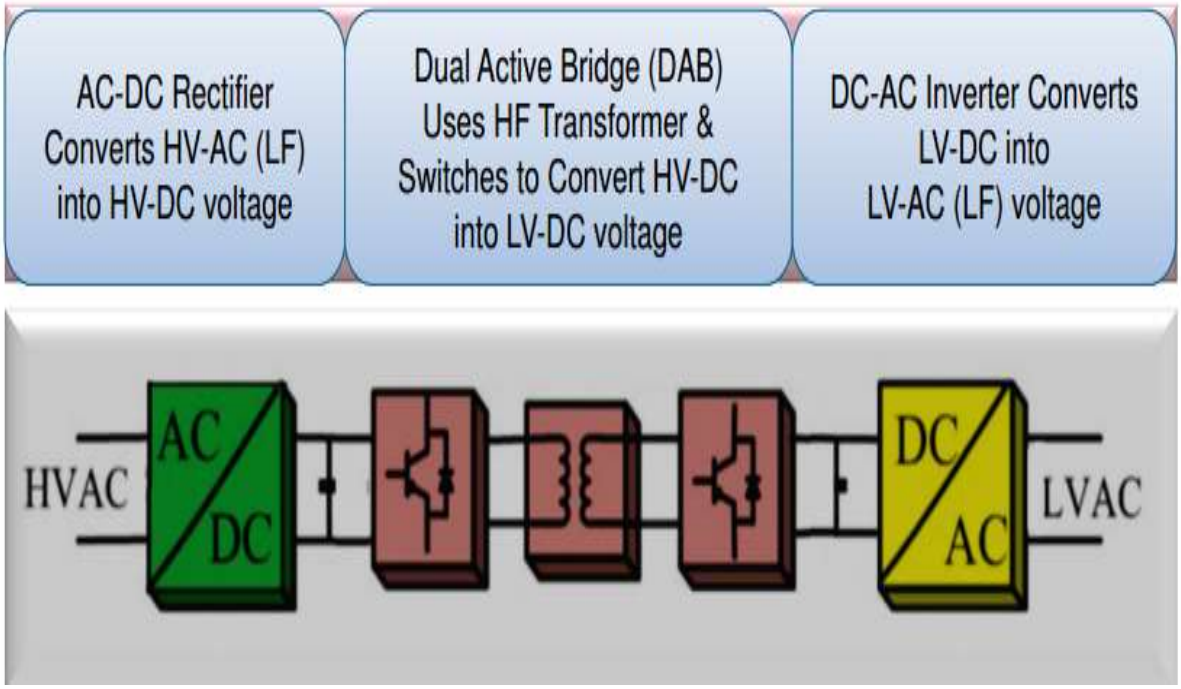

Fig. 2: *Basic Structure of SST.*

The SST works on the same principle of the conventional transformers, but here it operates at high frequency in order to reduce the weight and size. The incoming voltage is converted into high frequency AC by using power electronics converters and fed to the primary of the high frequency (HF) transformer to obtain AC and / or DC output voltage.

The ST is capable of integrating the distribution system, residential ac system, and envisioned dc system. In order to improve the system efficiency, the dc type sources and dc load are connected to the dc port, whereas the ac type sources and ac load are connected to ac port. The three-port characteristics of SST make it very suitable to enable a new micro grid that exhibits better performance compared with conventional ac and dc micro grids.

Smart transformers are used in a wide range of applications, which would facilitate the smooth transition from AC to DC and DC to AC, besides voltage conversion.

Role of Smart Transformer in Smart Grid[4]

1. During periods of power fluctuation smart transformers can be administered dynamically and also allow facilities to monitor and manage the transformers directly. Monitoring frequently helps in ensuring that their power supply remains voltage optimized even when new demands are being loaded upon it.
2. The power transfer between a micro grid and the utility grid is actively controlled without the need for communication to all micro grid elements.
3. Protect power system by isolating source and load from load disturbances harmonics, transients and voltage sags.
4. Enhance the power quality by summarizing the loads to the mains with identical phase current events for unbalanced loads.
5. Extension of Direct connection to future medium voltage DC power transmission, low voltage DC grid, storage systems and renewable energy systems feature is available.

Benefits of Smart Transformers

The smart transformers are designed to monitor and manage power supply during fluctuations and ensure that it is voltage optimized even when new demands are being placed upon it. Other benefits and functions of smart transformers include:

1. Protects the load from power supply disturbances.
2. Eliminates the tap changer requirement.
3. Provides backup and reduces outages length.
4. Control voltage and frequency levels will reduce the system losses.
5. Provide reactive power compensation and system harmonic filtering.

Applications of Smart Transformer [2,5]

1. Locomotives and other traction systems: The transformer used in current locomotive vehicles is 16.7Hz and is ±15% of the total weight of the locomotive. The ST can provide a significant weight reduction. Additionally, the ST is also able to improve the efficiency, reduce EMC, harmonics and acoustic emissions.
2. Desired energy generation: Offshore generation, whether from wind, tidal or any other source, can benefit from the reduction in weight and size. Beneficial reduction leads to smaller and cheaper offshore. Another advantage is that the ST can achieve unity power factor, thus, increasing the efficiency in power transmission.
3. Smart Grids: In future upcoming times, renewable generation is expected to increase, which creates an essential energy management scheme, which is fundamentally different from the classic methods. For fast and efficient management of the changes in different loads and sources, the ST can be used to dynamically adjust the energy distribution in the grid. The ST will manage the flow of energy.
4. Integration with other systems: The LV DC link in the ST topology delivers a worthy and readily available integration point for renewable energy systems into the distribution grid.
5. Application between generation source and load or distribution grid: In this scenario, the ST can enable constant voltage and frequency at its output if the input voltage and frequency are variable. The ST can too let the energy transport among source and load or grid to happen at unity power factor. This results in better utilization of the transmission lines and increased flow of active power. Another function, which the

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ST can provide is to improve system damping during the transient state.

6. Application between two distribution grids; One of the features of the ST is that it does not require both grids to have the same voltage level, frequency or to operate synchronously. The ST can be used to control the active power flow between both grids. It can also be used as a reactive power compensator for both grids. Special application is made, when considering the commercial side of power systems.
7. Connection between the MV and LV grid: In contrast to the CT, the ST can accurately control the amount of active power flowing from the MV to the LV grid. The ST can limit the amount of energy that flows back and forward through certain parts of the grid, to avoid overload of transmission lines with limited current carrying capacity.
8. Connection between MV-grid and loads: LV loads are often unbalanced which can lead to harmonics disturbances in the voltage and asymmetrical voltages. When the discrepancy is huge or comprises of many non-linear loads, the adding of a neutral wire might not nullify the disturbances wholly. In this case, the ST can support by generating a voltage that barely suffers from unbalanced and non-linear loads.

Comparison of ST & CT

In spite of its worldwide use, the CT suffers from numerous disadvantages. Few of these are:

- Bulky size and heavy weight
- Transformer oil can be harmful when exposed to the environment
- Core saturation produces harmonics, which results in large inrush currents
- Output has always influence of input. Any Unwanted characteristics on the input side (such as voltage dips) get represented in output waveform as Harmonics where output current has an influence on the input. The harmonics can propagate into the network or lead to an increase of primary winding losses depending on the transformer connection.
- As voltage regulation is inversely proportional to its rating. At distribution level, the transformers are generally small and voltage regulation is not very good as all CTs suffer from non-perfect voltage regulation.

Alternative to the CT is SST. Other functions and benefits of the ST which are absent in the CT are High controllability due to the use of power electronics.

1. By the relational concept that “The transformer size is inverse proportional to its frequency”. Hence, higher frequency results in a smaller transformer, reduced size and weight.
2. The power correction facility is possible because the AC/DC stage acts as a power correction device and hence we can have Unity power factor. 20% of the available active power usually gets increased by Unity power factor.
3. As there is a presence of DC links in the SST it won't get affected by voltage swell /sag
4. Capability to maintain output power for a few cycles due to the energy stored in the DC link capacitor.
5. Function as circuit breaker. The electricity flow gets stopped and the circuit gets interrupted, when the power electronics used in the SST are turned off.
6. Fast fault detection and protection.

Scope of Smart Transformer

Fig. 3: *Future Scope of Smart Transformer.*

KEY MARKET TRENDS

Distribution Transformers to Dominate the Market

1. The growing emphasis on renewable energy generation across the world, coupled with increasing electrical infrastructure projects, is expected to drive the demand for distribution transformers during the forecast period, in turn driving the smart transformers market.
2. In the electric distribution grid, smart transformers work independently to monitor and regulate the voltage while maintaining a contact with the smart grid. Even by remote administration the information about the transformer and the power supply can be known. Hence, this enables for proper load management, resulting in better power quality and lesser power outages.
3. Developed economies, such as the United States, European Countries, and Japan, contribute to the significant demand for smart transformers, owing to the increasing replacement of aging power distribution equipment, and increase in the integration of renewable to the grid.[1]

MARKET OVERVIEW

Fig. 4: *Market Overview Asian – Pacific.*

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Asia-Pacific to Dominate the Market

1. The great dominance in the smart grid network market is by Asian pacific in 2018. Expected to continue its dominance in the coming years as well. The countries such as China, India, and Japan are back up countries in these networks.
2. China has the ambition to become a world leader in electrical power equipment by 2025. Large amounts of funding are allocated to support the development.
3. India stands as the 3rd -largest electricity-generating nation in the world (2018). Accounting the power being generated including both conventional and renewable sources. The country has made major strides in improving access to power among both rural and urban communities through various government-led schemes focused on Power for All.
4. For modernization of the power utility sector, the country made its first move with National Smart Grid Mission (NSGM) announced in May 2015, with an outlay of INR 980 crore and a budgetary support of INR 338 crore.
5. Moreover, in remote places, where the cost of installation of power grids can be high, it becomes comparatively less expensive for the government to deploy renewable energy sources for power generation and increase the electrification rate, thus propelling the market for distribution transformers in the country.

CONCLUSION

Smart transformers will be highly popular in the future because their intelligence embedded is capable enough to meet the requirements of upcoming power systems. The smartness of Smart transformers is more beneficiary one over conventional off-load and on-load tap changer transformers which helps in solving overcoming several issues associated with distribution network and smart grid operation. Reduced grid losses, improved power quality, load management with advanced monitoring facility and supply reliability are some of the attributes of smart transformers.

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