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Solid State Transformer (SST) "Review of Recent Developments"

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Abstract

The transformer has been used throughout the twentieth century. Until now, it has consisted of a configuration of iron or steel cores and copper/aluminum coils, with mineral oil serving as both coolant and dielectric medium. Inherent in this type of construction are regulation, significant weight, losses, environmental concerns, and power quality issues. For the 21st century, a new kind of power electronics transformer is developed one that can be made self-regulating, coil-free, and able to correct power quality problems. The solid-state transformer allows add-on intelligence to enhance power quality compatibility between source and load. This new transformer is insensitive to harmonics, prevents harmonics from propagating (in either direction), has zero regulation, prevents load disruptions and faults from affecting the primary system, can supply loads with dc offsets, and does not utilize a liquid dielectric. The purpose of this paper is to give the idea about this developing power electronic transformer also known as Solid state transformer. The brief review of various developments in SST technology is given here.

Keywords: Component: Solid State Transformer (SST), High Frequency Transformer (HF Transformer), HV/MV/LV Link.

1. Introduction

Transformers are fundamental components of the power distribution system and are relatively inexpensive, highly reliable, and fairly efficient. However, they possess some undesirable properties including sensitivity to harmonics, voltage drop under load, (required) protection from system disruptions and overload, protection of the system from problems arising at or beyond the transformer, environmental concerns regarding mineral oil, and performance under dc-offset load unbalances [1]. These disadvantages are becoming increasingly important as power quality becomes more of a concern. With the advancement of power electronics circuits and devices, the all solid-state transformer becomes a viable option to replace the conventional copper-and-iron based transformer for a better power quality. Past researches that attempted to introduce solid-state transformer concept can be found in the literature [2–7]. The solid-state switching technologies allow power conversion between different formats such as dc/dc, dc/ac, ac/dc, and ac/ac with any desired frequencies. The term "solid-state transformer" has been defined and appeared in literatures [2–3].

The objective of this paper is to provide an overview of the basic concepts of SST. Also the brief review of SST's various configuration is discussed including converter topologies. Finally; some functionalities of SST are described in brief.

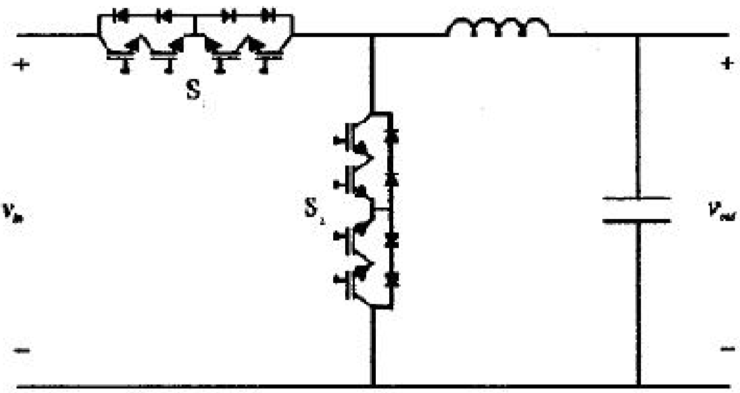

Fig. 1: AC to AC Buck converter.

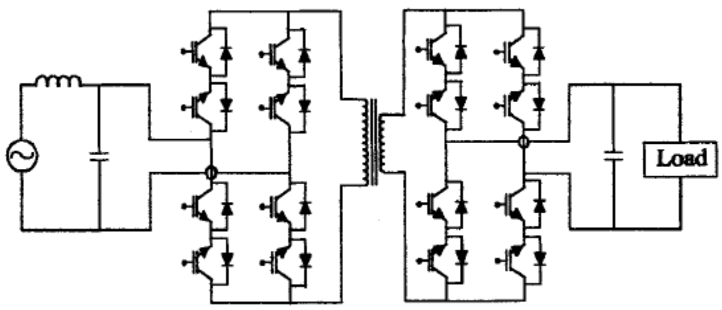

Fig. 2: HF Modulated AC/ac converter.

2. Backgrond of Solid State Transformer Technology

The idea of a "solid-state transformer" has been discussed for some time. Nearly 20 years ago, Navy researchers [2] proposed a power-electronic transformer that consisted of an ac/ac buck converter shown in Fig. 1. To reduce the input voltage to a lower one. This was followed in 1995 by a similar EPRI sponsored effort [3]. Both of these efforts yielded working prototypes, but they operated at power and primary voltage levels that were orders of magnitude below utility distribution levels.

Another attempt at high-power ac/ac conversion has been proposed in [8]. For that topology, shown in Fig. 2, the incoming ac waveform is modulated by a power-electronic converter to a high-frequency square wave and passed through a small high-frequency transformer. Another converter, synchronous with the high-voltage side but at a lower voltage, demodulates it. This scheme has the benefit of reducing the transformer size and weight and the stress factor is more reasonable, but it does not provide any benefits in terms of control or power-factor improvement [8].

3. Basic Structure of Solid State Transformer

The basic structure of a SST is depicted in Fig. 3. The isolation is achieved through an HF transformer. The grid voltage is converted into a higher frequency AC voltage through the use of power-electronics based converters before to be applied to the primary side of the HF transformer. The opposite process is performed on the HF transformer secondary side to obtain an AC and/or DC voltage for the load.[3]

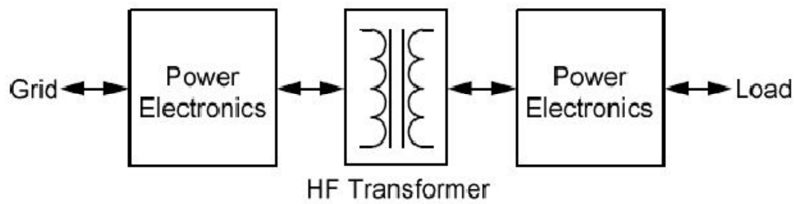

Fig. 3: Basic Solid State Transformer Structure.

4. Various Solid State Transformer Configurations

The selection of the appropriate topology for the SST implementation is a key aspect. In [9] the issue is addressed by comparing some of the potential topologies that support bidirectional power flow as a minimum requirement. In order to select these potential topologies for comparison, a number of topologies proposed for SST as well as for general AC-AC power conversion have been surveyed.

An approach to classify the SST topologies and select the appropriate configuration according to the specific needs was introduced in [9]. In this classification, as seen in Figure:3, four SST configurations that cover all the possible SST topologies are identified: a) single-stage with no DC link, b) two-stage with low voltage DC (LVDC) link, c) two stage with high voltage DC (HVDC) link, and d) three-stage with both HVDC and LVDC links. The DC link of the third configuration is not appropriate for DES and DER integration since it is high voltage and has no isolation from the grid; therefore, topologies under that classification are not practical for SST implementation. [9]

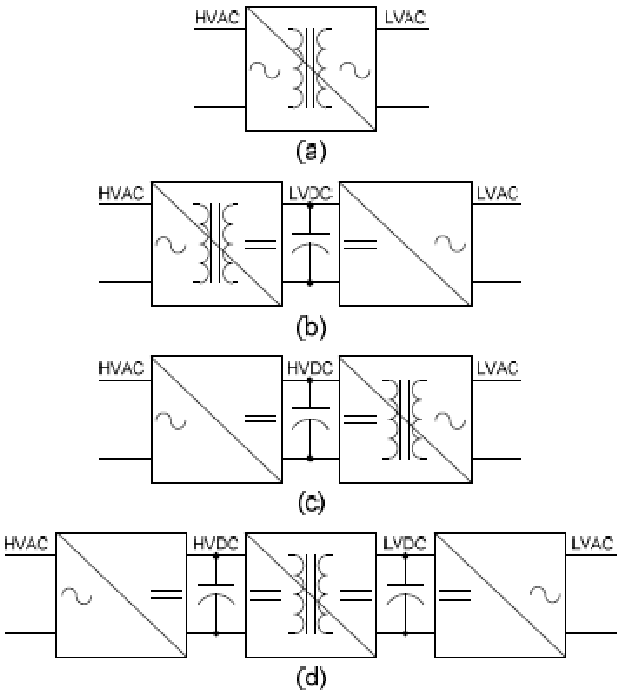

Fig. 4: SST configurations: (a) single-stage, (b) two-stage with LVDC link, (c) two-stage with HVDC link, and (d) three-stage.

5. Solid State Transformer: Functionalities

1. Protects load from power supply disturbances
2. Voltage Harmonics and sag compensations
3. Outage compensation
4. Protects power systems from the load disturbances
5. Load transients and harmonic regulations
6. Unity input power factor under reactive load
7. Sinusoidal input current for non linear loads
8. Protection against output short circuit
9. Operates on distributed voltage level
10. Integrates energy storage
11. Medium frequency isolation

6. Solid State Transformer: Future Benifits

6.1 Integration with other systems

The LV DC link in the SST topology provides a good and readily accessible integration point for renewable energy systems into the distribution grid. A unidirectional converter could be used when the load demand is much bigger than the renewable energy generation capabilities. Where the peak generation capabilities exceed the load demand during certain periods, the excess power could be fed back into the grid by using a bidirectional converter.

6.2 DC as a Means of Power Delivery

The SST concept is ideally suited to extend the use of DC, both in MV and LV applications. The difficulty in interrupting a DC feeder under fault conditions is often cited as a major hurdle in the acceptance of DC distribution in MV applications. The use of the power electronic interface (SST) to generate the DC is a means of controlling the system and interrupting fault currents.[13]

7. Conclusion

In this paper, technological review of concepts and developments in field of Solid State Transformer has been shown. Also various topologies and configuration used and implemented so far has been briefly reviewed. The comparison b/w this various topologies of solid state transformer has been summarized. Finally it is concluded that the conventional transformer which was used widely in industrial applications so far having disadvantages like saturation of core for non linear load, poor voltage regulation, bulkiness. Majority of these problems can be reduced or completely eliminated by solid state power electronic based intelligent transformer. Also it has the capability to work as energy router for smart grid energy internet. So field of application of power electronic based solid state transformer now a day's not limited up to only distribution level but research work suggested that this intelligent solid state transformers are having capacity to replace the conventional power transformer too in near future.

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