Solid State Transformer for Smart Grid System Application

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***Abstract* -** Due to the increased complexity new methods are required to manage the changing loads and sources. A solid-state transformer (SST) is the solution and it would not only provide the efficient functioning as a conventional transformer but also provide other benefits, particularly on-demand reactive power maintenance for the grid, good power quality, current limiting, and voltage conversion. As it is a high frequency transformer, several topologies for SST have been presented by research agencies. This paper presents the development in power electronics transformer, a review of SST topologies is presented here.

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

I. INTRODUCTION

In the last few years, European countries have started to open their electricity market due to this there is an increased penetration of renewable energy and other distributed generation sources in the grid. These developments cause the network layout and operation to become much more complex, new technologies are required that allow better control, bi-directional power flow and increased number of power inputs.

The SST gives way to control the routing of electricity and provides easy methods for interfacing distributed generation with the grid. The solid-state transformer also controls power flow, which is required to ensure a stable and safe operation of the grid. However, this comes at the cost of a more complex and expensive system. A typical SST made up of an AC/DC rectifier, a DC/DC converter with HF transformer and a DC/AC inverter. SST has a similar function to that of a traditional line frequency transformer (LFT), namely increasing/decreasing the voltage.

Previous research that attempted to introduce solid-state transformer concept can be found in the reference [3–7]. The solid-state switching technologies allow power conversion between different formats such as dc/dc, ac/ac, ac/dc, and dc/ac with any desired frequencies. This paper provides an overview of the basic concepts of SST. Also the brief review of SST's configuration is also discussed including converter topologies& application in the grid.

II. SOLID STATE TRANSFORMER CONCEPT

The basic structure of a SST is shown in Fig. 1. The HF transformer is used as a isolator. The grid voltage is converted into a HF AC voltage through the use of power-electronics converters before applied to the primary of the HF transformer. The opposite process is performed on the High Frequency transformer secondary to get an AC and/or DC voltage for the load. [4].

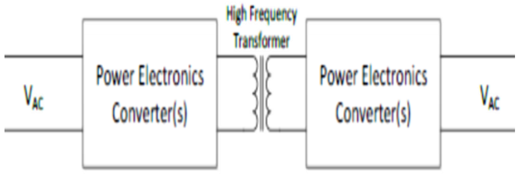


Fig. 1 Basic structure of SST

The traditional Line Frequency Transformer (LFT) has been used since the introduction of AC systems for voltage conversion and isolation. The widespread use of this device has resulted in a cheap, efficient, reliable and mature technology and any increase in performance are marginal and come at great cost [9] Additional features of the SST not found in Line frequency transformer are as below [2]:

1. Reduced size and weight.
2. Instantaneous voltage regulation.
3. Fault isolation.
4. Power factor correction.
5. Control of active and reactive power flow.
6. Fault current management on low-voltage and high voltage side.
7. Active power filtering of harmonic content on the input.
8. Good voltage regulating capabilities
9. The output can have a different frequency and number of phases than the input
10. Possibility of a DC input or output
11. Voltage dip and sag ride though capability (with enough energy storage)

III. SOLID STATE TRANSFORMER CONFIGURATIONS

The SST architectures developed in the last 10 years can be categorized as [10]:

1) SST based on their topologies:
2) SST based on their application:
3) SST architectures with focus on switching devices

Different research teams used different topologies and architectures for the Solid State Transformer.

Schematic Overview of SST based on topologies

The Solid State Transformer made up of one or more power electronics converters with an integrated high-frequency transformer. Based on the topologies, SST can be classified in four categories [11].

1) Single-stage with no DC link(Figure 2.a)
2) Two-stage with a DC link on the secondary side (Figure 2.b)
3) Two-stage with a DC link on the primary side (Figure 2.c)
4) Three-stage with a DC link on both the primary and secondary side(Figure 2.d)

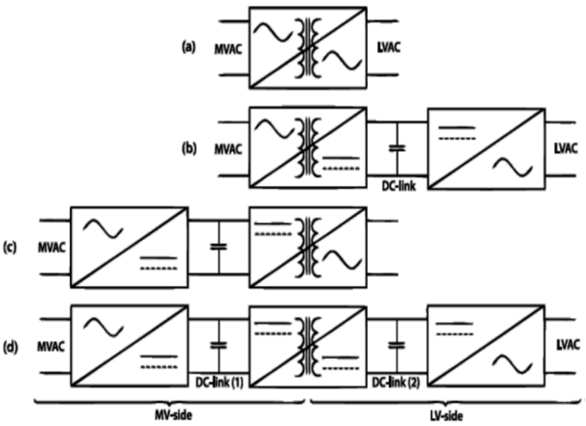


Fig.2: SST architectures [11][12]

Out of these four possible classifications, architecture from fig.2 .d, with two DCs, is the feasible because it has high flexibility and control performance. The DC links decouple the MV-from the LV-side, allowing for independent reactive power control and input voltage sag ride-though. This topology also allows better control of voltages and currents on both primary and secondary side[11][12][13].It consists of an AC-DC conversion stage at the MV-side, a DC-DC conversion stage with high-frequency transformer for isolation and a DC-AC conversion stage at the LV-side.

IV. APPLICATIONS OF THE SOLID STATE TRANSFORMER

Due to additional advantages, the application of the SST in some areas is much attractive. These applications are [1][12][13]:

1. Locomotives and other traction systems
2. Offshore energy generation
3. Smart Grids

The transformer used in current locomotive vehicles is 16.7Hz and is ±15% of the total weight of the locomotive. The SST can provide a significant weight reduction. Additionally, the SST is also able to improve the efficiency, reduce EMC, harmonics and acoustic emissions [14].

Offshore generation, whether from wind, tidal or any other source, can benefit from the reduction in weight and size. This reduction leads to smaller and thus cheaper offshore platforms. Another advantage is that the SST can achieve unity power factor, thus increasing the efficiency in power transmission.

In future power systems, the usage of renewable generation is expected to increase, and will require an energy management scheme that is fundamentally different from the classic methods. For fast and efficient management of the changes in different loads and sources, the SST can be used to dynamically adjust the energy distribution in the grid. The function of the SST as described in this scenario is similar to that of a router, but instead of managing data, the SST will manage the flow of energy. For this reason, the SST is sometimes also called an energy router [15]

The application of the Solid State Transformer for smart grids

The following applications of the Solid state transformer are possible [11].

A. Application between generation source and load or distribution grid (Figure 3.a+b)

In this scenario, the SST can enable constant voltage and frequency at its output if the input voltage and frequency are variable. The SST can also allow the energy transport between source and load or grid to occur at unity power factor. This results in better utilization of the transmission lines and increased flow of active power. Another function, which the SST can provide ,is to improve system damping during the transient state.

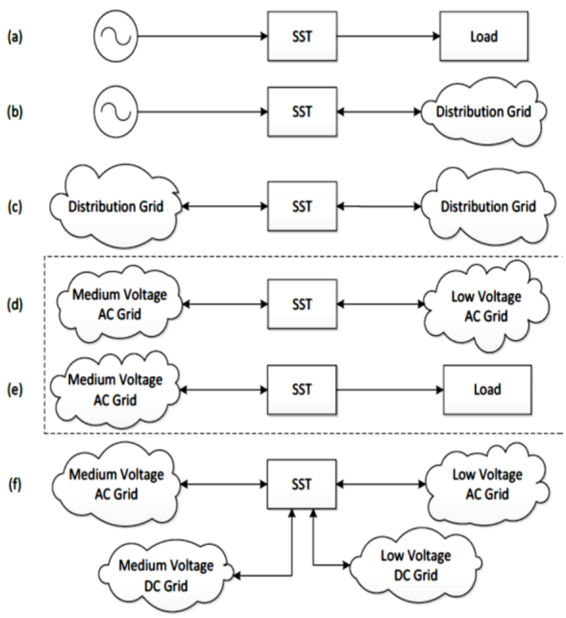


Fig.3: Schematic overview of the SST applications

B. Application between two distribution grids (Figure 3.c)

One of the features of the SST is that it does not require both grids to have the same voltage level, frequency or to operate synchronously. The SST 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 .A special application in Figure 2.5.c is when considering the commercial side of power systems. During periods when energy in grid 2 is cheaper than in grid 1, the operator of grid

1 can reduce its own generation and buy the energy from grid 2[10].

C. Connection between the MV-and LV-grid (Figure 3.d)

In contrast to the LFT, the SST can accurately control the amount of active power flowing from the MV-to the LV-grid. This is useful if the LV-side also has generation sources such as PV-panels. The SST 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.

D. Connection between MV-grid and loads (Figure 3.e)

LV-loads are often unbalanced which can lead to harmonics disturbances in the voltage and asymmetrical voltages. A neutral wire is added in order to eliminate these disturbances and achieve a more symmetrical voltage. When the imbalance is large or consists of many non-linear loads, the addition of a neutral wire might not nullify the disturbances completely. In this case, the SST can help by generating a voltage that hardly suffers from unbalanced and non-linear loads.

E. Application as interface for distributed generation and smart grids (Figure .3d)

Distributed energy sources, such as photovoltaic arrays and wind turbines, provide a variety of electric sources. These sources often have a varying voltage or frequency or can even be a DC voltage. The SST is flexible enough to allow connection of these sources to the traditional grid.

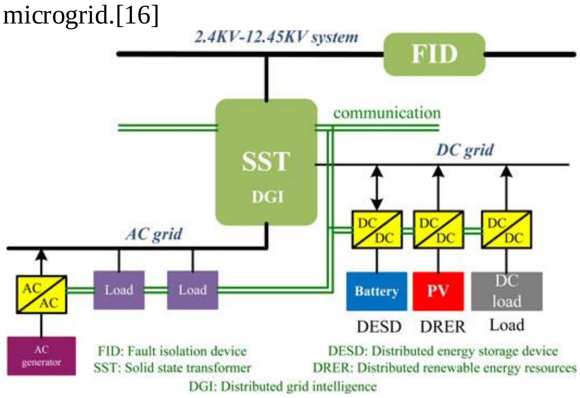
Future Benefits of solid state transformer

Integration with other systems The LV DC link in the SST topology provides a good and flexible integration point for renewable energy systems in the distribution grid. When the load demand is higher than the renewable energy source capabilities then a unidirectional converter could be used. Where the highest generation capabilities exceed the load demand during certain periods, then the excess power could be fed back to the grid by using a bidirectional converter.

DC as a Means of Power Delivery

The Solid state transformer 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 SST to generate the DC is a means of controlling the system and interrupting fault currents. [13]

In 2008, innovative distribution system architecture, called the future renewable electric energy delivery and management (FREEDM) system, was proposed as shown in Figure.Instead of the traditional transformer, the SST is used to interface the low-voltage ac residential system with the distribution system. In addition, the distributed renewable energy resources (DRER) and the distributed energy storage devices (DESD) are connected to the dc port of the SST, composing a dc microgrid.[16]



CONCLUSION

In this paper, concepts and developments in field of SST has been shown. Also use of this SST in the field of FREEDM system and the comparison between this various topologies of SST has been summarized. Finally it is concluded that the conventional transformer having disadvantages like bulkiness, poor voltage regulation saturation of core for non linear load, Majority of these problems can be eliminated by solid state power electronic transformer. Also it has the ability to work as energy router for smart grid energy internet. therefore application of power electronic based SST now a day's not limited up to distribution level but research work suggested that SST are having ability to replace the conventional transformer too in near future.

V. REFERENCES

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