MATLAB Simulink Model of Dual Active Bridge Converter for Solid State Transformer

Bharat Bhushan Khare
Student
Department of Electrical Engineering
UIT, RGPV Bhopal
bharatbhushankhare1996@gmail.com

Dr. Vinay Thapar
Professor
Department of Electrical Engineering
UIT, RGPV Bhopal
vinaythapar@rgtu.net

Abstract*— Solid State Transformer (SST) is one of the emerging technologies for smart distribution system. It can be used as an energy router in the energy delivery and management system. In this paper, the basic architecture of SST is discussed and a MATLAB simulink model of dual active bridge converter is designed. Phase shift control technique is used to design the controller. The simulation results are also presented here.

Keywords— *Solid State Transformer, Power Electronic Converters, Dual Active Bridge, High Frequency Transformer etc.*

Nomenclature—

SST - Solid State Transformer
HFT- High Frequency Transformer
DAB- Dual Active Converter
HVDC – High Voltage DC Link
LVDC – Low Voltage DC Link
HVAC - High Voltage AC Link
V_{dc_H} – Input Voltage of DAB
V_{dc_L} – Output Voltage of DAB
n – Turn Ration of HFT

I. INTRODUCTION

Solid state transformer is also known as electronic transformer, intelligent universal transformer and power electronics transformer and is a combination of power electronic converters and high frequency transformer [1-3]. In 1970 William MC Murray has patented this transformer and named it ‘Electronic Transformer [2, 3]. In order to improve the performance of SST many researchers have developed their models.

SST offers several advantages such as voltage sagcompensation, fault isolation, power factor correction, harmonic isolation and additional DC output etc, over its conventional counterpart; however, the cost of SST is approximately five times higher than that of conventional transformer [1, 4, 5].

SST has varied applications, such as in DC micro-grid, fast charging stations for electric vehicles, traction system etc [1, 6, 7]. When real time monitoring system is used with SST, it is called smart transformer [8]. The Basic structure of SST is shown in figure 1, here the High frequency Transformer (HFT) is connected in the middle of Power electronic converters.

Based upon the converters configuration SST can be classified into four types which are A, B, C and D as shown in figure 2 [1, 9, 10].

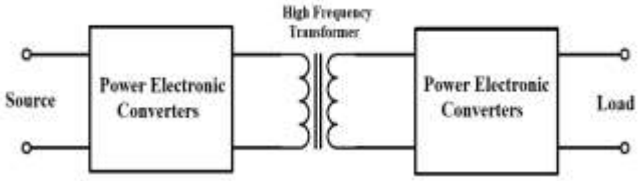

Fig. 1 Basic structure of SST [1]

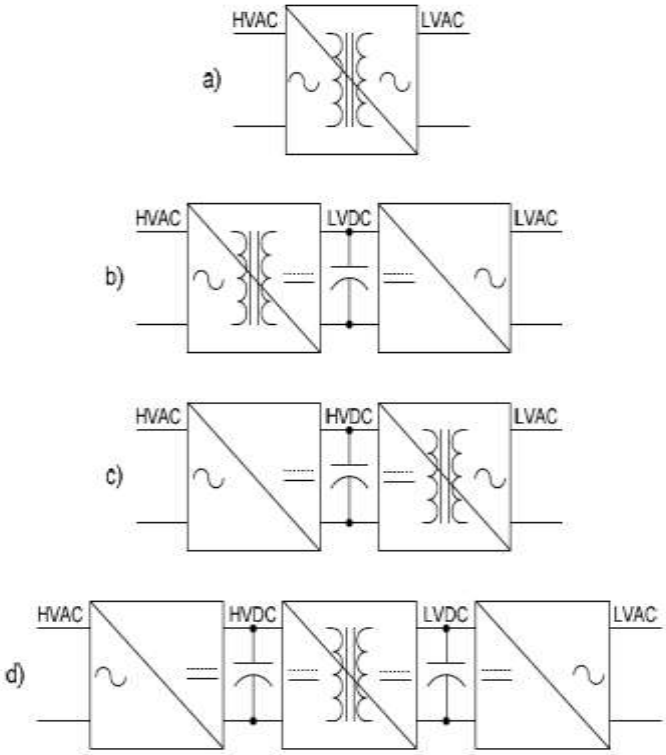

Fig. 2 Topology of SST [9]

In type A, direct AC to AC conversion is performed, whereas in type B and C, either high voltage DC (HVDC) link or Low Voltage DC (LVDC) link is present in the type D, both HVDC and LVDC link is present. In the type D, the input AC is converted into HVDC through rectifier then HVDC is converted into LVDC through isolated DC to DC converter and then LVDC is converted into Low voltage AC (LVAC) link.

Various types of converters are used at DC-DC conversion stage such as full bridge DC-DC converter, Series Resonant Converter and Dual Active Bridge (DAB) Converter etc. out of that DAB converter is widely used.In this paper, the

MATLAB Simulink model of DAB converter is presented using phase shift control technique.
The rest of the paper is divided four sections. The section II deals with the configuration of DAB converter. In section III the parameters of selected DAB and its MATLAB Simulation model is shown. The results of simulation are presented in section IV and conclusions are given in section V.

II. CONFIGURATION OF DAB CONVERTER

Bidirectional isolated dc-dc DAB converters was initially proposed by De Doncker et al., in 1991 [11].This has benefits as zero voltage switching (ZVS), bidirectional power flow, and lower component stresses.
The circuit diagram of the DAB converter is shown in Figure. 3.

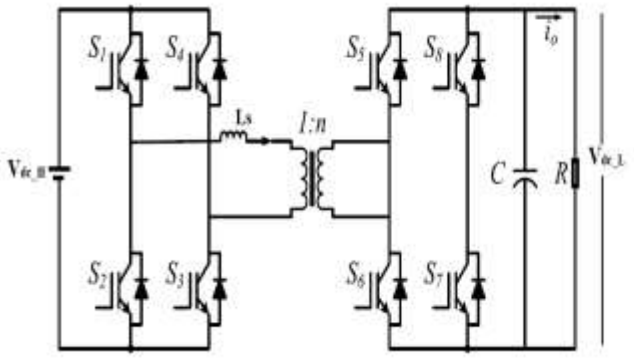

Fig. 3 Circuit diagram of the DAB converter

In this figure, S_1 to S_8 are the switching devices used to construct the converter, V_{dc_H} and $V_{dc_L}$is the voltage of input and output respectively. Io is the output current of DAB and n:1 in the turn ratio of HFT.
Various types of materials are used in the core of HFT, such as ferrite, amorphous and Nano-crystalline [1, 2, 10]. In all these type, Nano-crystalline material is best candidate to construct the core of HFT [12]. For the winding to compensate the high frequencies losses, Litz wire is used [12]. For the switching devices, Sic semiconductor based devices are currently being used [13].

In the DAB, neglecting the switching losses, the amount of transferred power being controlled by the duty cycle, is given by [14]

$$P = \frac{nV_{dc_H} V_{dc\_L} D(1-D)}{2 f_s L}$$

Where, L is the inductance of HFT and f_s its switching frequency.
The steady state waveform of the single phase shift (SPS) control method of the DAB converter is shown in Figure4. Here duty cycle is represented by "D".

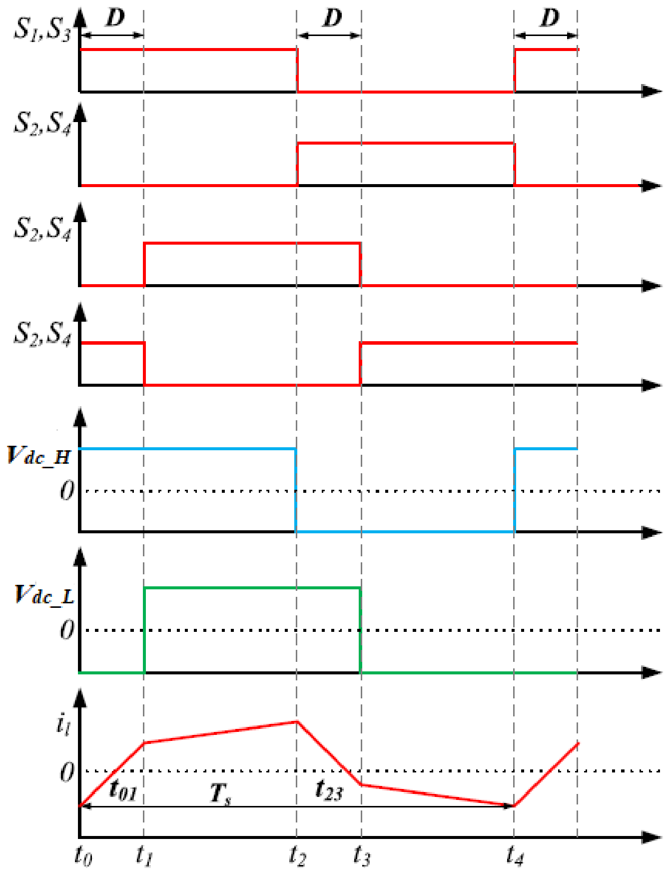

Fig. 4 Waveform of the DAB converter

III. MATLAB SIMULATION MODEL

MATLAB Simulink model of Dual Active Bridge is shown in figure 5. Phase shift controller is used to control the converters, connected on both side of HFT. The model for controller is shown in figure 6.
The Simulink parameters used to construct the DAB Converter in MATLAB is shown in table 1.

Table 1 Simulation Parameters

Sr.No.	Parameter Nmae	Value
1	Input Voltage	3 kV
2	HFT Turn Ratio	8
3	Switching Frequency	1 kHz
4	Output Voltage	400 V
5	L (Filter)	0.135 mH
6	C (Filter)	150 µF
7	Load (R)	60 ohm

The primary and secondary side voltages of high frequency transformer is shown in figure 7 and the output waveforms of voltage and current are shown in figure 8.

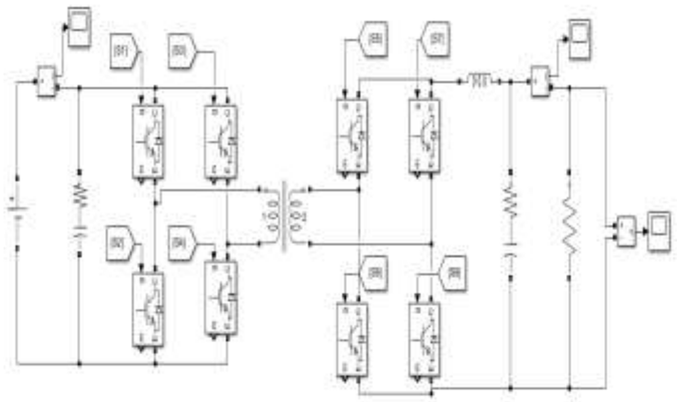

Fig. 5 MATLAB Simulink model of DAB

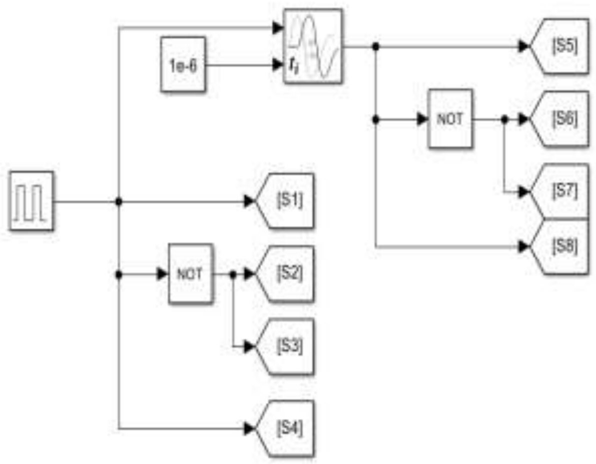

Fig. 6 Phase shift controller

IV. RESULTS

The primary and secondary side voltages of high frequency transformer is shown in figure 7, which shown the proper phase shifting between primary and secondary side voltages and the output waveforms of voltage and current are shown in figure 8.

V. CONCLUSION

DAB converter can be an important part of three stage solid state transformer because the controlling is easy. It is easy to connect PV system and energy storing devices at the LVDC side

of DAB to fulfill the energy requirement at local ends. DAB converter can also be used for direct AC-AC conversion butit can not be used where DC load present and the controlling will became complex however the size of SST will be reduced.

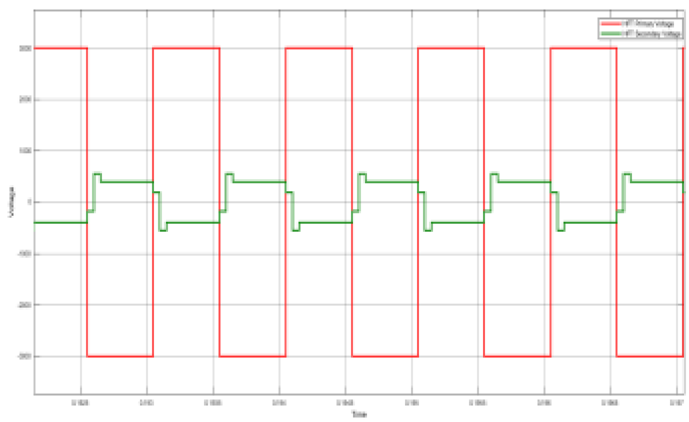

Fig. 7 Primary and Secondary Side Voltage of HFT

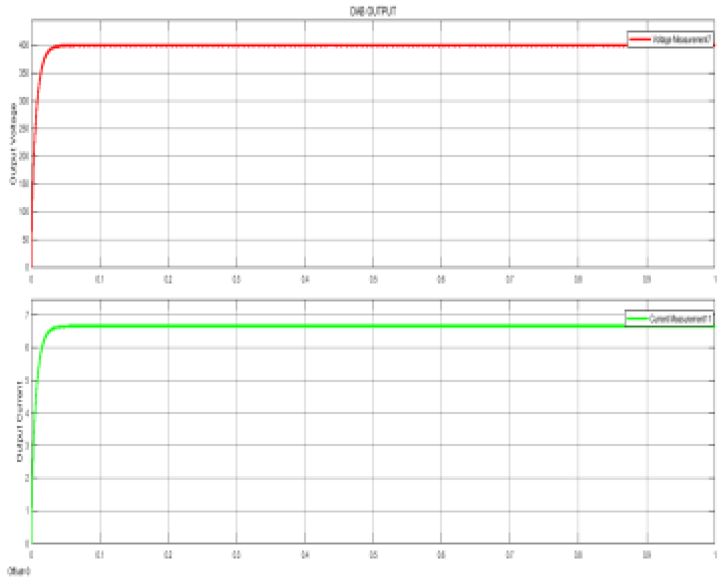

Fig. 8 output waveform of voltage and current

REFERENCES

[1] X. She, A. Q. Huang and R. Burgos, "Review of Solid-State Transformer Technologies and Their Application in Power Distribution Systems," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 1, no. 3, pp. 186-198, Sept. 2013, doi: 10.1109/JESTPE.2013.2277917.

[2] X. She, R. Burgos, G. Wang, F. Wang and A. Q. Huang, "Review of solid state transformer in the distribution system: From components to field application," 2012 IEEE Energy Conversion Congress and Exposition (ECCE), 2012, pp. 4077-4084, doi: 10.1109/ECCE.2012.6342269.

[3] M. A. Hannan et al., "State of the Art of Solid-State Transformers: Advanced Topologies, Implementation Issues, Recent Progress and Improvements," in IEEE Access, vol. 8, pp. 19113-19132, 2020, doi: 10.1109/ACCESS.2020.2967345.

[4] T. Zhao et al., "Module Power Balance Control and Redundancy Design Analysis of Cascaded PV Solid-State Transformer Under Fault Conditions," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 9, no. 1, pp. 677-688, Feb. 2021, doi: 10.1109/JESTPE.2020.2964950.

[5] J. Shi, W. Gou, H. Yuan, T. Zhao and A. Q. Huang, "Research on voltage and power balance control for cascaded modular solid-state transformer," in IEEE Transactions on Power Electronics, vol. 26, no. 4, pp. 1154-1166, April 2011, doi: 10.1109/TPEL.2011.2106803.

[6] A. C. Nair and B. G. Fernandes, "A Solid State Transformer based Fast Charging Station for Various Categories of Electric Vehicles with Batteries of Vastly Different Ratings," in IEEE Transactions on Industrial Electronics, doi: 10.1109/TIE.2020.3038091.

[7]X. She, A. Q. Huang, S. Lukic and M. E. Baran, "On Integration of Solid-State Transformer With Zonal DC Microgrid," in IEEE Transactions on Smart Grid, vol. 3, no. 2, pp. 975-985, June 2012, doi: 10.1109/TSG.2012.2187317.

[8] A. Milczarek and M. Malinowski, "Comparison of Classical and Smart Transformers Impact on MV Distribution Grid," in IEEE Transactions on Power Delivery, vol. 35, no. 3, pp. 1339-1347, June 2020, doi: 10.1109/TPWRD.2019.2941641.

[9] M. A. Hannan et al., "State of the Art of Solid-State Transformers: Advanced Topologies, Implementation Issues, Recent Progress and Improvements," in IEEE Access, vol. 8, pp. 19113-19132, 2020, doi: 10.1109/ACCESS.2020.2967345.

[10] Shamshuddin MA, Rojas F, Cardenas R, Pereda J, Diaz M, Kennel R. Solid State Transformers: Concepts, Classification, and Control. *Energies*. 2020; 13(9):2319. https://doi.org/10.3390/en13092319

[11] S. Srinivasan, A. K. Parvathy and P. Deivasundari, "Dual active bridge — A good candidate for solid state transformer," 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), 2017, pp. 1321-1326, doi: 10.1109/ICPCSI.2017.8391924.

[12] B. Chen, X. Liang and N. Wan, "Design Methodology for Inductor-Integrated Litz-Wired High-Power Medium-Frequency Transformer With the Nanocrystalline Core Material for Isolated DC-Link Stage of Solid-State Transformer," in IEEE Transactions on Power Electronics, vol. 35, no. 11, pp. 11557-11573, Nov. 2020, doi: 10.1109/TPEL.2020.2987944.

[13] M. A. Rahman, M. R. Islam, K. M. Muttaqi and D. Sutanto, "Modeling and Control of SiC-Based High-Frequency Magnetic Linked Converter for Next Generation Solid State Transformers," in IEEE Transactions on Energy Conversion, vol. 35, no. 1, pp. 549-559, March 2020, doi: 10.1109/TEC.2019.2940042.

[14] Y. Wang et al., "A Dual-Active-Bridge With Half-Bridge Submodules DC Solid-State Transformer for DC Distribution Networks," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 9, no. 2, pp. 1891-1904, April 2021, doi: 10.1109/JESTPE.2020.2992688.