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A Solid State Transformer Integrating Distributed Generation and Storage

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Abstract: The development of a Solid State Transformer (SST) that incorporates a DC-DC multiport converter to combine both photovoltaic (PV) power generation and battery energy storage. The DC-DC stage is based on a quad active-bridge (QAB) converter which not merely provides isolation for the load, but also for the PV and storage. The AC-DC stage is implemented with a pulse-width-modulated (PWM) single phase rectifier. Terminology to determine the power rating of the MAB ports is also derived. The QAB demanded power is calculated at the QAB controls and then fed into the rectifier controls in order to minimize the effect of the interface between the two SST stages. The voltage performance of the designed control loops based on the proposed control strategies are verified through extensive simulation of the SST average and switching models.The implementation of the virtual image as been made using MATLAB

Keywords: DC-DC converter,distributed generation,mult- port converte,smart grid,solid state transformer.

I. INTRODUCTION

1.1 DC-DC CONVERTER

The SST and the multi-port converters are two key areas of research, the work presented herein has been motivated by the better integration that the SST can achieve with the use of multi-port converters.The three-stage configuration that has been identified as a potential candidate for the SST implementation relies on a DC bus for PV and storage integration. This is achieved through separate DC-DC converters Without isolation, the voltage ratings of these devices must be selected mainly based on the DC bus voltage rating. If voltage ratings are not compatible and/or isolation is required, then additional isolation is needed, thus increasing the size of the system. Furthermore, separate controllers for each DC-DC converter are to be designed. In this design process, the stability of the interconnected DC-DC converters must be ensured. The proposed SST is based on a particular type of multi-port converter, called quad-active-bridge (QAB) converter, to integrate PV and storage. This SST topology eliminates the need of additional isolation and only an integrated controller for the DCDC stage may be required.

In the last decade the smart grid theory has drawn the attention of researchers and the industry as a possible solution attention of researchers and the industry as a feasible solution to the challenges that the electrical system is opposite due to the increase in load, the increasing saturation of renewables, and the exploitation of the distributed generation at the consumer. The power-electronics-based transformer, or so-called solid-state transformer (SST), is one of the input components of the distribution system proposed by Future Renewable Electric Energy Delivery and Management Systems interior. Besides helping as a regular distribution transformer, the SST provides ports for the proper integration of distributed generation (DG) and energy storage, thus enhancing the reliability of the distribution system. Additionally, the SST enables the implementation of distributed intelligence through a secure communication network (COMM) to ensure the stability and optimal operation of the distribution system.The SST interfacing photovoltaic (PV) generation, storage, dc and ac loads, as well as plug-in hybrid electric vehicles (PHEV). The fault identification device (FID) is used for shielding the SST.

The selection of the appropriate topology for the SST implementation is a key aspect. The three-stage configuration based on a dual-active-bridge (DAB) converter has been recognized as a potential candidate for the SST implementation. This topology relies on a low-voltage-dc (LVDC) link for PV and storage integration. This is achieved during separate non isolated dc–dc converters. The voltage rating of these converters must be chosen mostly based on

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the LVDC voltage. If their voltage ratings are considerably different from the LVDC voltage and/or isolation is necessary for grounding, then additional HF transformers may be desired, thus increasing the size of the system. Furthermore, separate controllers for each dc–dc converter are to be designed. To ensure the stability of the controllers, their interaction may require to be examined.

The require of technology for integrating DG and storage into the distribution system has motivated the growth of a new making of power converters. A family of multiport dc–dc converters, which includes the multi active-bridge (MAB) converters, has been proposed by researchers. Their advantage deceit in the combination of several sources with minimum dc–dc conversion stages, which yields a higher power density. Since the SST considered herein includes the grid, the load, the PV system, and the storage, a four-port dc–dc converter as the quad-active-bridge (QAB) converter is necessary. This paper proposes the development of a SST based on a QAB converter, to combine DG and storage. The QAB converter, used in the implementation of the SST dc–dc stage, provides isolation for DG and storage through a single four-winding HF transformer and the control design involves the analysis of merely a single converter

II. PROPOSED TOPOLOGY

The SST review starts with the accessible topologies for the implementation of the SST, considering their limitations and strengths to support additional functionalities as compare to a regular distribution transformer. Simulations of some of the functional capabilities are presented based on a three-stage SST topology. 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 take an AC and/or DC voltage for the load.

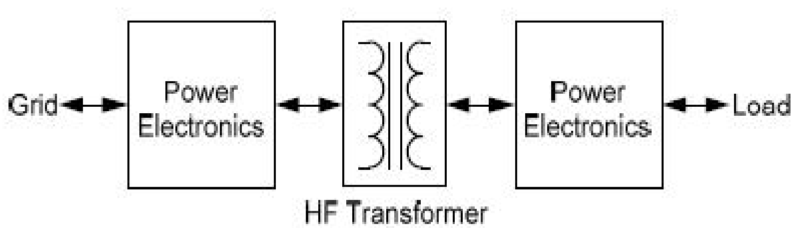

Fig. 1 Basic SST structure

2.1 SST Topologies

The selection of the proper topology for the SST implementation is a input aspect. In the issue is addressed by comparing some of the potential topologies that support bidirectional power flow as a minimum necessity. 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. An approach to classify the SST topologies and select the appropriate configuration according to the specific desires was introduced. In this classification, 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

2.2 SST Function

a)Output voltage regulation: Under normal conditions, the output voltage at each phase is independently controlled to be 120Vrms for most types of loads.

b)On-demand reactive power support to grid: The SST responds to a reactive power command for grid support by injecting or absorbing reactive current into the grid. The actual amount of reactive power is issue to the SST VA rating.

c)Output over current protection: This is achieved through an inner current loop that limits the instantaneous load current. As a result, the SST output switches from a constant-voltage mode into a constant-current mode.

d)Input over current protection: During input voltage sags, the SST input current increases in order to keep the input active power constant. If the input current tends to increase beyond its maximum allowable value, the controls go inside into a constant input current type. In this type, the key active power no longer meets the load active power demand. As a result, the HVDC voltage will drop at a constant rate.

e)Under voltage trip on HVDC link: The SST discontinues serving the load when the HVDC voltage reaches its minimum allowed value to avoid over modulation on the grid side. At this point, the output voltages are forced to zero.

f)LVDC link for distributed generation and storage: The LVDC link is accessible to connect DES, DER and DC loads. DES and DER units are required to function as current sources to avoid interference with the LVDC link voltage regulation.

g)Storage management: During transients, the SST generates an active power command for a connected DES device when the active power drawn from the grid is less than the load demand. This helps the SST ride through sustained input voltage sags. In steady state operation, the SST executes the pre-scheduled charging discharging of the DES.

h)Islanded mode of operation. When the distribution system is disconnected from the grid, the SST key side can be commanded to switch from the normal power-injection type into a voltage regulation type, which is achieved through droop-control techniques. The simulation results from testing some of the above functional capabilities. The transient response to a step reference command for reactive power support. Here the HVDC voltage remains untroubled.

2.3 QUAD ACTIVE BRIDGE

The three-stage DAB-based SST with the integration of PV and storage through separate non-isolated converters. The proposed SST topology, presented herein, replaces the DAB with a QAB. The two remaining

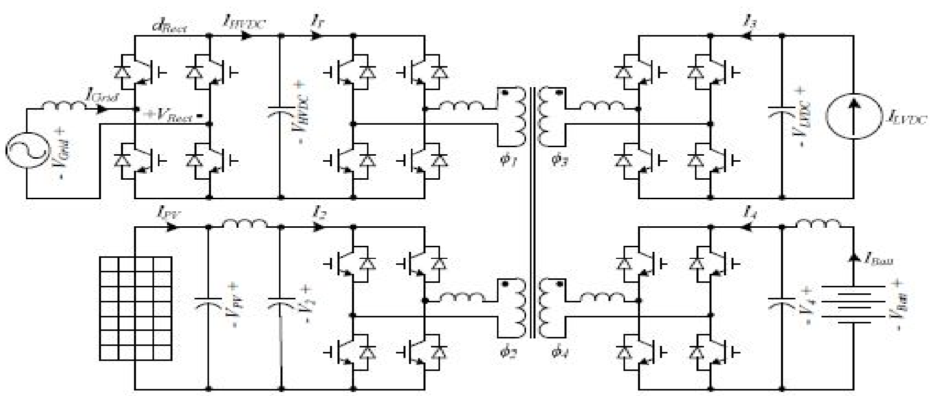

Fig.2 QUAD ACTIVE BRIDGE

Ports are reserved for PV and storage integration. The power will be injected into SST not through the LVDC link, but directly through the HF transformer. DAB-based SST with storage and PV interfaced to LVDC link. QAB-based SST with storage and PV.A detailed analysis of the QAB converter is performed in the next chapter. This is the basis for the control design of the DC-DC stage of the SST

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2.4 DAB converter

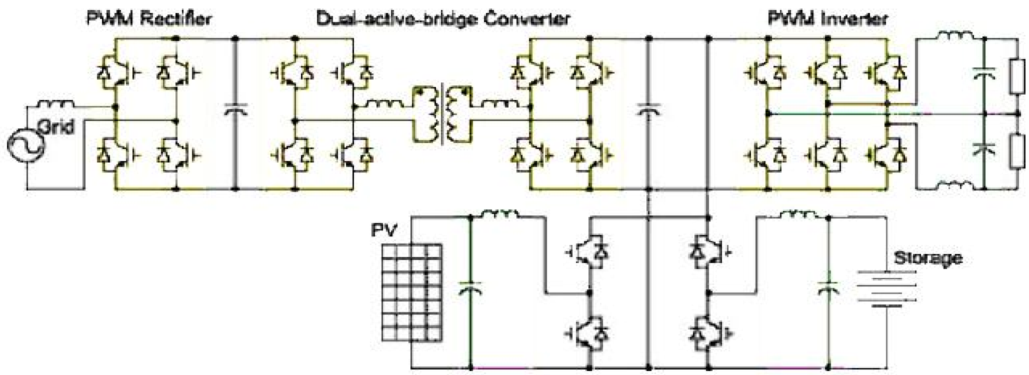

Fig. 3 DAB circuit diagram

The power that flows between any two ports is controlled through phase-shift modulation (PSM) of the square wave voltages generated at their corresponding AC sides. The dual-active-bridge (DAB) converter introduced can be considered the simplest MAB converter. The equation derived therein for the DAB cycle-by-cycle average (CCA) power can be extended to any MAB converter.

The MAB converters have recently gained the attention of researchers as potential solutions for the integration of renewables with isolation. The advantages of this type of converters are

1) Interconnection of sources with different voltage ratings by adjusting the HF transformer turn ratios
2) Single controller design.
3) Zero voltage switching (ZVS) capability.
4) And high power density. On the other side, the complexity of the HF transformer as well as the controller design considerably increases with the number of ports. The ZVS operating region for a DAB converter derived

III. SIMULATION RESULT

DUAL AVTIVE BRIDGE

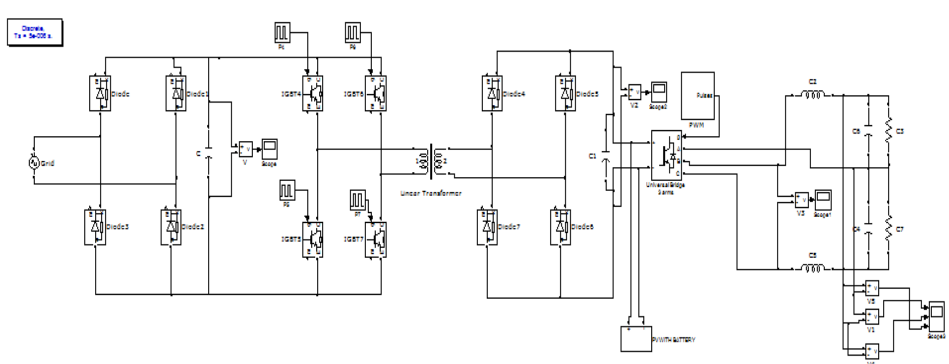

Fig .4 Dual Active Bridge

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The simulation of the interconnected AC-DC and DC-DC stages is performed.

In order to verify the dynamic performance of all the SST controls, a step load current is applied at the LVDC port of the SST.

The outputs show good reference command following under disturbances. However, the performance of the HVDC voltage regulation greatly improves when using the feedforward approach. As a consequence, the grid current does not overshoot.

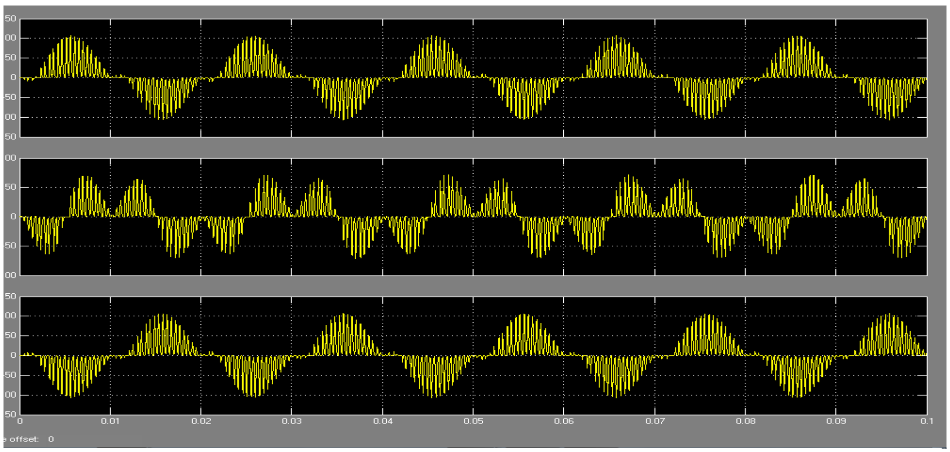

Fig. 5 DAB Simulation

QUAD AVTIVE BRIDGE

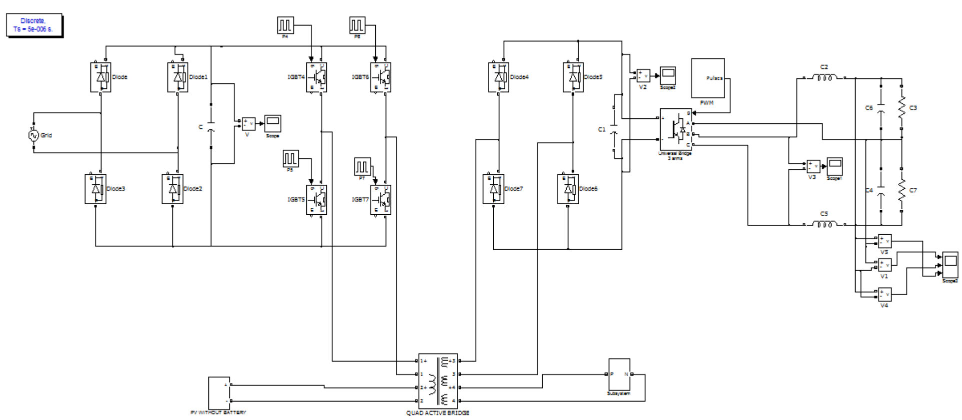

Fig. 6 QAB Circuit

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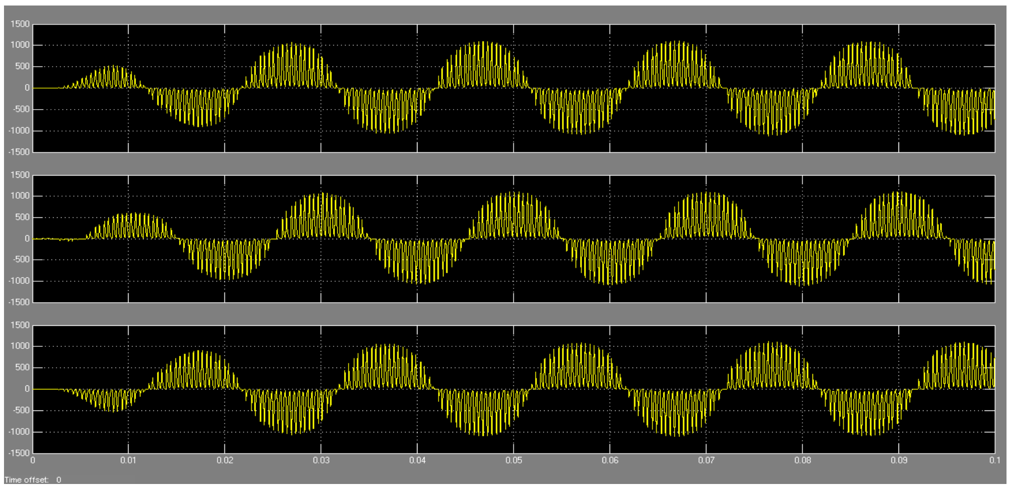

Fig. 7 QAB Simulation

3.2 QAB-based SST Topology

The three-stage DAB-based SST with the combination of PV and storage through separate non-isolated converters. The proposed SST topology, replaces the DAB with a QAB. The two remaining ports are reserved for PV and storage integration. The power will be injected into SST not through the LVDC link, but directly through the HF transformer. DAB-based SST with storage and PV interfaced to LVDC link. QAB-based SST with storage and PV interfaced to LVDC & HVDC link

IV. CONCLUSION

A SST topology based on a quad-active-bridge (QAB) converter which provides isolation for the load, as well as DG and storage. Additionally, the expressions to find out the power rating of an MAB port have been derived and used to find out the power rating of the QAB ports in view of the operating characteristics of the SST application. This type of controller allows the access to all state variables, thus enabling a feed forward technique to enhance the performance of the HVDC voltage regulation on the AC-DC stage. The power demanded by the QAB is estimated and fed into the AC-DC stage controller. This is a simple yet effective approach that helps minimize the interaction between the two SST stages. The dynamic performance of the designed QAB control loops based on the proposed SISO technique as well as the MIMO approach are verified through extensive simulation of the SST average and switching models. When enabling the feed forward technique for the operation of the complete SST, the HVDC voltage regulation significantly improves.

REFERENCES

[1] Hassan, R.; Radman, G.; , "Survey on Smart Grid," IEEE SoutheastCon 2010 (SoutheastCon), Proceedings of the , vol., no., pp.210–213, 18–21 March 2010.

[2] Huang, A.Q.; Baliga, J.; , "FREEDM System: Role of power electronics and power semiconductors in developing an energy internet," Power Semiconductor Devices & IC's, 2009. ISPSD 2009. 21st International Symposium on, vol., no., pp.9–12, 14–18 June 2009.

[3] Heydt, G.T.; , "Future renewable electrical energy delivery and management systems: Energy reliability assessment of FREEDM systems," Power and Energy Society General Meeting, 2010 IEEE , vol., no., pp.1–4, 25–29 July 2010.

[4] Karady, G.G.; Xing Liu; , "Fault management and protection of FREEDM systems," Power and Energy Society General Meeting, 2010 IEEE , vol., no., pp.1–4, 25–29 July 2010.

[5] Tiefu Zhao; Liyu Yang; Jun Wang; Huang, A.Q., "270 kVA Solid State Transformer Based on 10 kV SiC Power Devices," Electric Ship Technologies Symposium, 2007. ESTS '07. IEEE, vol., no., pp.145–149, 21–23 May 2007.

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[6] Tao, H.; Kotsopoulos, A.; Duarte, J.L.; Hendrix, M.A.M.; , "Family of multiport bidirectional DC-DC converters," Electric Power Applications, IEE Proceedings- , vol.153, no.3, pp. 451– 458, 1 May 2006.
[7] Falcones, S.; Xiaolin Mao; Ayyanar, R.; , "Topology comparison for Solid State Transformer implementation," Power and Energy Society General Meeting, 2010 IEEE , vol., no., pp.1–8, 25–29 July 2010.
[8] Heinemann, L.; Mauthe, G., "The universal power electronics based distribution transformer, an unified approach," Power Electronics Specialists Conference, 2001. PESC. 2001 IEEE 32nd Annual, vol.2, no., pp.504–509 vol.2, 2001.
[9] Krishnamurthy, H.; Ayyanar, R.; , "Stability analysis of cascaded converters for bidirectional power flow applications," Telecommunications Energy Conference, 2008. INTELEC 2008. IEEE 30th International , vol., no., pp.1–8, 14–18 Sept. 2008.
[10] S. Falcones, X. Mao, R. Ayyanar, "Simulink Block-set for Modeling Distribution Systems with Solid State Transformer," in Proc. Future Renewable Electric Energy Distribution Management Annual Conference 2009, North Carolina State University, Raleigh, NC, May 18–19, 2009, pp. 181–184.
[11] Subhashish Bhattacharya, Tiefu Zhao, Gangyao Wang, Sumit Dutta, Seunghun Baek, Yu Du, Babak Parkhideh, Xiaohu Zhou, and Alex Q. Huang, "Design and Development of Gen-1 Silicon based Solid State Transformer", in Proc. FREEDM Annual Conference 2009, North Carolina State University, Raleigh, NC, May 18–19, 2009, pp. 69–74. 93
[12] S. Falcones, X. Mao, and R. Ayyanar "Simulation of the FREEDM Green Hub with Solid State Transformers and Distributed Control" in Proc. Future Renewable Electric Energy Distribution Management Annual Conference 2010, Florida State University, Tallahassee, FL, 2010.
[13] De Doncker, R.W.A.A.; Divan, D.M.; Kheraluwala, M.H., "A three-phase softswitched high-power-density DC/DC converter for high-power applications," Industry Applications, IEEE Transactions on, Volume: 27 Issue: 1 Part 1, Jan/Feb 1991, Page(s): 63–73.
[14] Zhao, C.; Kolar, J., "A Novel Three-phase Three-Port UPS Employing a Single High-Frequency Isolation Transformer," Power Electronics Specialists Conference, 2004 ,vol. 6, June 2004, pp. 4135–4141.
[15] Tao, H.; Kotsopoulos, A.; Duarte, J.L.; Hendrix, M.A.M., "A Soft-Switched Three-Port Bidirectional Converter for Fuel Cell and Supercapacitor Applications," Power Electronics Specialists Conference, 2005. PESC '05. IEEE 36th , vol., no., pp.2487–2493, 2005.
[16] Falcones, S.; Ayyanar, R.; , "Simple control design for a three-port DC-DC converter based PV system with energy storage," Applied Power Electronics Conference and Exposition (APEC), 2010 Twenty-Fifth Annual IEEE , vol., no., pp.2149–2153, 21–25 Feb. 2010.
[17] Qiang Mei; Xu Zhen-lin; Wei-yang Wu; , "A novel multi-port DC-DC converter for hybrid renewable energy distributed generation systems connected to power grid," Industrial Technology, 2008. ICIT 2008. IEEE International Conference on , vol., no., pp.1–5, 21–24 April 2008.
[18] Mei Qiang; Wu Wei-yang; Xu Zhen-lin; , "A Multi-Directional Power Converter for a Hybrid Renewable Energy Distributed Generation System with Battery Storage," Power Electronics and Motion Control Conference, 2006. IPEMC 2006. CES/IEEE 5th International , vol.3, no., pp.1–5, 14–16 Aug. 2006.
[19] Qing Chen; Lee, F.C.; Jian Zhong Jiang; Jovanovic, M.M.; , "A new model for multiple-winding transformer," Power Electronics Specialists Conference, PESC '94 Record., 25th Annual IEEE , vol., no., pp.864–871 vol.2, 20–25 Jun 1994.