A Triple Active Bridge DC-DC Converter Capable of Achieving Full-Range ZVS

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***Abstract-* This project deals with a triple active bridge converter capable of achieving ZVS across the full load range with wide input voltage while minimizing heavy load conduction losses. This topology comprises three full bridges coupled by a three-winding transformer. By adding a third full bridge to the traditional DAB, ZVS operation is maintained at light load without penalty on conduction loss at heavy load, while maintaining the same total semiconductor area. The input DC voltage supplied to the triple active bridge DC to DC converter with different transformer ratio is used to obtain high and low voltage as output. By using triple active bridge , multi range of output can be obtained and multiple loads can be connected . Multi range of output in the sense the transformer used in this topology consist of one primary winding and many secondary can be connected to get the desired output.**

I. INTRODUCTION

In developing modern power electronic converters, several design considerations come into play. System level specifications must first be identified based on power rating and bus voltages, which coincide with ancillary power electronic systems (i.e. grid-tied inverters, battery charge converters, etc.). A converter topology must then be selected and designed to meet the aforementioned requirements. Advanced modeling techniques must be applied in order to develop appropriate control schemes, which stabilize the converter and enable intelligent power flow. Finally, a working system must be constructed and tested using selected components and a digital controller.

Operating switching converters at higher frequencies will reduce overall system size, which will make new applications for such converters more feasible. However, current silicon based designs are limited in their frequency of operation capabilities due to the excessive losses they incur during hard switching phases. Silicon carbide semiconductor devices exhibit material properties, which make them an optimal choice when high frequency operation is desired. When these devices are employed, higher density power converters can be realized. Applications for such converters include distributed generation in the future smart grid, plug-in electric vehicles, space exploration, and various extreme environment electronic systems. power converters using silicon semiconductor devices, and found to be quite large do to their excessive losses and relatively low switching frequency.

The proposed system is designed to achieve the multiple range of voltage using triple active structure, to reduce the switch stress, to improve the switching performance and to get the desired output using PI controller. At first dual active bridge is used to transfer the power with reduced loss, but the disadvantage in this system is it contains so many components and switches. So the switch stresses will be increased. Inorder to reduce the stress researchers go for triple active bridge.The triple active bridge consist f the semiconductor switch IGBT and the freewheeling diode. The function of the freewheeling diode is to freewheels the voltage back to the source.The three active bridges are connected by the high frequency transformer.

II. LITERATURER SURVEY

[1] A three-phase soft-switched high-power-density DC/DC converter for high-power applications , R. W. De Doncker, D. M. Divan, and M. H. Kheraluwala "IEEE Transactions on Industry Applications, vol.27, no.1, pp.63, 73, Jan/Feb 1991".

Three DC/DC converter topologies suitable for high-power-density high-power applications is presented. All three circuits operate in a soft-switched manner, making possible a reduction in device switching losses and an increase in switching frequency. The three-phase dual-bridge converter proposed is shown to have the most favorable characteristics. This converter consists of two three-phase inverter stages operating in a high-frequency six-step mode. In contrast to existing single-phase AC-link DC/DC converters, lower turn-off peak currents in the power devices and lower RMS current ratings for both the input and output filter capacitors are obtained. This is in addition to smaller filter element values due to the higher-frequency content of the input and output waveforms. Furthermore, the use of a three-phase symmetrical transformer instead of single-phase transformers and a better utilization of the available apparent power of the transformer (as a consequence of the controlled output inverter) significantly increase the power density attainable.

[2] Modulation strategy to operate the dual active bridge DC-DC converter under soft switching in the whole operating range, G.G. Oggier, G.O. Garcia, A.R. Oliva," IEEE Transactions on Power Electronics, vol.26, no.4,"pp.1228, 1236, April 2011.
A new modulation strategy that allows operating the dual active bridge (DAB) dc-dc converter under soft switching in the whole operating range is proposed. This strategy is ruled by imposing a certain modulation index in one of the two bridges and a phase shift between the transformer primary and secondary voltages. Moreover, the proposed algorithm reduces the reactive power and thus reducing the converter conduction losses. An experimental prototype was implemented and some experimental results are presented to validate the theoretical analysis. The experimental results reveal that the overall efficiency of the DAB topology can be improved up to 20% by implementing the proposed modulation strategy instead of the conventional one.

[3] "A bidirectional isolated dc–dc converter as a corecircuit of the next-generation medium-voltage power conversion system, S. Inoue and H. Akagi, "IEEE Transactions on Power Electronics," vol. 22, no. 2, pp. 535–542,Mar. 2007.
This paper describes a bidirectional isolated dc-dc converter considered as a core circuit of 3.3-kV/6.6-kV high-power-density power conversion systems in the next generation. The dc-dc converter is intended to use power switching devices based on silicon carbide (SiC) and/or gallium nitride, which will be available on the market in the near future. A 350-V, 10-kW and 20 kHz dc-dc converter is designed, constructed and tested. It consists of two single-phase full-bridge converters with the latest trench-gate insulated gate bipolar transistors and a 20-kHz transformer with a nano-crystalline soft-magnetic material core and litz wires. The transformer plays an essential role in achieving galvanic isolation between the two full-bridge converters. The overall efficiency from the dc-input to dc-output terminals is accurately measured to be as high as 97%, excluding gate drive and control circuit losses from the whole loss. Moreover, loss analysis is carried out to estimate effectiveness in using SiC-based power switching devices

[4] "A bidirectional dc–dc converter for an energy storage system with galvanic isolation, S. Inoue and H. Akagi,"IEEE Transactions on Power Electronics, vol. 22, no. 6, pp. 2299–2306, Nov. 2007.
This paper addresses a bidirectional dc-dc converter suitable for an energy storage system with an additional function of galvanic isolation. An energy storage device such as an electric double layer capacitor is directly connected to a dc side of the dc-dc converter without any chopper circuit. Nevertheless, the dc-dc converter can continue operating when the voltage across the energy storage device drops along with its discharge. Theoretical calculation and experimental measurement reveal that power loss and peak current impose limitations on a permissible dc-voltage range. This information may be useful in design of the dc-dc converter

[5] Performance optimization of a high current dual active bridge with a wide operating voltage range, F. Krismer, S. Round, and J. Kolar," Power Electronics Specialists Conference," vol., no., pp.1, 7, 18-22 June 2006
The main aim of this paper is to improve the performance of high current dual active bridge converters when operated over a wide voltage range. A typical application is for fuel cell vehicles where a bi-directional interface between a 12V battery and a high voltage DC bus is required. The battery side voltage ranges from 11V to 16V while the fuel cell is

operated between 220V and 447V and the required power is typically 1kW. Careful analysis shows that the high currents on the battery side cause significant design issues in order to obtain a highs efficiency. The standard phase shift modulation method can result in high conduction and switching losses. This paper proposes a combined triangular and trapezoidal modulation method to reduce losses over the wide operating range. Approximately, a 2% improvement in efficiency can be expected. An experimental system is used to verify the improved performance of the dual active bridge using the proposed advanced modulation method.

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III. EXISTING SYSTEM

This paper proposes a three winding transformer based triple active bridge (TAB) dc-dc converter. FB1 (full bridge 1) and FB2 (full bridge 2) are two input full bridges, while FB3 (full bridge 3) is the output full bridge. They are coupled by a high frequency transformer, which has three windings (turns ratio is N1:N2:N3).Power flow between the three full bridges is mainly controlled by adjusting $\phi3,1$ (phase shift between FB3 and FB1) and $\phi2,1$ (phase shift between FB2 and FB1).This topology with an additional bridge provides multiple benefits to converter operation. It is able to have ZVS at entire load range through simple phase-shift control of all bridges. At heavy load, defined as operation mode 1 ($\phi2,1=0$, $0<\phi3,1\leq0.5$) in this paper, both input bridges operate synchronously to reduce conduction loss by sharing the input current equally, as shown . At light load as operation mode 2 ($0<\phi2,1 \leq\phi3,1\leq0.5$) and mode 3 ($0<\phi3,1<\phi2,1\leq0.5$), one of input full bridges (such as FB2) reverses power flow and thereby increases circulating current to achieve soft switching. The existing system is capable of achieving ZVS across the full load range with wide input voltage while minimizing heavy load conduction losses to increase overall efficiency. This topology comprises three full bridges coupled by a three-winding transformer. At light load, by adjusting the phase shift between two input bridges, all switching devices can maintain ZVS due to a controlled circulating current. At heavy load, the two input bridges work in parallel to reduce conduction loss.

CVBLOCK DIAGRAM OF EXISTING SYSTEM

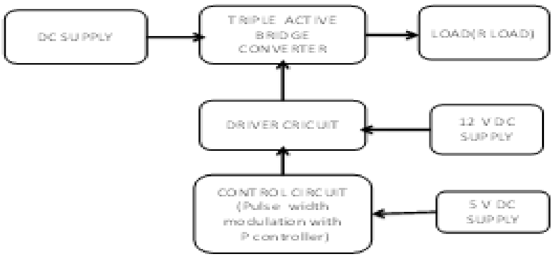


Figure 1: Block diagram of existing system

Historically, bipolar semiconductor devices (i.e, diode, transistor, thyristor, thyristor, GTO etc) have been the front runners in the quest for an ideal power electronic switch. Ever since the invention of the transistor, the development of solid-state switches with increased power handling capability has been of interest for expending the application of these devices. The BJT and the GTO thyristor have been developed over the past 30 years to serve the need of the power electronic industry. Their primary advantage over the thyristors has been the superior switching speed and the ability to interrupt the current without reversal of the device voltage. All bipolar devices, however, suffer from a common set of disadvantages, namely, limited switching speed due to considerable redistribution of minority charge carriers associated with every switching operation; relatively large control power requirement which complicates the circuit design. Besides, bipolar devices can not be paralleled easily

The reliance of the power electronics industry upon bipolar devices was challenged by the introduction of a new MOS gate controlled power device technology in the 1980s. The power MOS field effect transistor (MOSFET) evolved from the MOS integrated circuit technology. The new device promised extremely low input power levels and no inherent limitation to the switching speed. Thus, it opened up the possibility of increasing the operating frequency in power electronic systems resulting in reduction in size and weight. The initial claims of infinite current gain for the power MOSFET were, however, diluted by the need to design the gate drive circuit to account for the pulse currents required to charge and discharge the high input capacitance of these devices. At high frequency of operation the required gate drive power becomes substantial. MOSFETs also have comparatively higher on state resistance per unit area of the device cross section which increases with the blocking voltage rating of the device. Consequently, the use of MOSFET has been restricted to low voltage (less than about 500 volts) applications where the ON state resistance reaches acceptable values. Inherently fast switching speed of these devices can be effectively utilized to increase the switching frequency beyond several hundred kHz. From the point of view of the operating principle a MOSFET is a voltage controlled majority carrier device. As the name suggests, movement of majority carriers in a MOSFET is controlled by the voltage applied on the control electrode (called gate) which is insulated by a thin metal oxide layer from the bulk semiconductor body. The electric field produced by the gate voltage modulate the conductivity of the semiconductor material in the region between the main current carrying terminals called the Drain (D) and the Source (S). Power MOSFETs, just like their integrated circuit counterpart, can be of two types (i) depletion type and (ii) enhancement type. Both of these can be either n- channel type or p-channel type depending on the nature of the bulk semiconductor. Fig 6.1 (a) shows the circuit symbol of these four types of MOSFETs along with their drain current vs gate-source voltage characteristics (transfer characteristics).

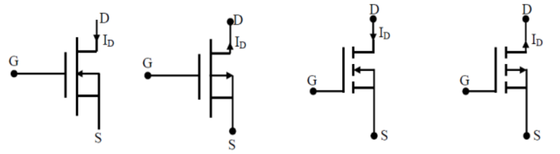
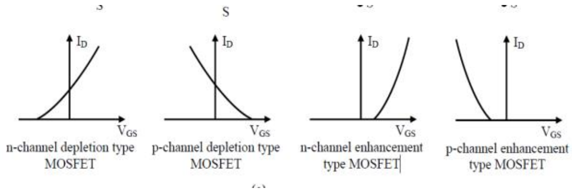


Figure 2 : symbols of MOSFET



n-channel depletion type MOSFET
p-channel depletion type MOSFET
n-channel enhancement type MOSFET
p-channel enhancement type MOSFET

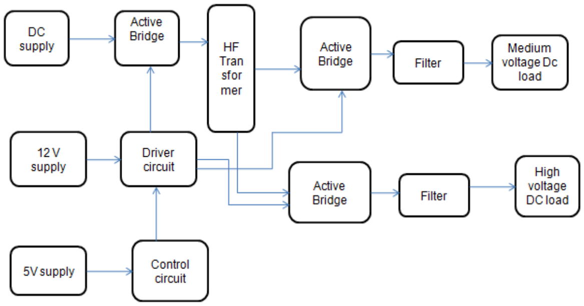
Figure 3 : Characteristics of MOSFET

VI. PROPOSED SYSTEM

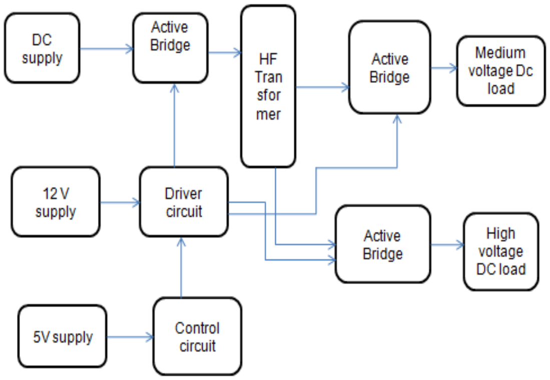
The proposed system has triple active bridge DC to DC converter with isolated transformer in the topology. The input voltage supplied to the active bridge converter is split into two different voltage level by the multiple winding transformer. At any given input the design may achieve the accurately higher efficiency by PI controller and which is used for fine tuning so that gate terminal will receive the pulse without any distortion, this will result in the best approximation to the optimal prior to the selection of specific devices to implement the converter. The proposed system consist of two types. They are system with filter and system without filter. The system with filter consist of the output which is free from ripple content. The system without filter consist of the output which contains ripple. PI controller used is to reduce the forced oscillation and to avoid the disturbances caused due to the oscillations. It is also having maximum overshoot.

When compared to P controller is having maximum high overshoot.

BLOCK DIAGRAM OF PROPOSED SYSTEM WITH FILTER



BLOCK DIAGRAM OF PROPOSED SYSTEM WTHOUT FILTER



The block diagram of proposed system consist of three active bridges, high frequency transformer, filter , input supply ,medium and high DC load. Two or more wire windings placed around a common magnetic core is the physical structure of a transformer. It's electrical purpose is to transfer power from the primary winding to the other windings with no energy storage or loss. For HW# 1 show the B-H curve for a transformer with transferred and core loss energy indicated.

The choice of circuit topology obviously has great impact on the transformer design. Flyback transformer circuits are used primarily at power levels in the range of 0 to 150 Watts, Forward converters in the range of 50 to 500 Watts, half-bridge from 100 to l000 Watts, and full bridge usually over 500 Watts. The waveform and frequency of currents in transformers employed in these unique circuit topologies are unique. Initiatively we expect all windings employed on a given transformer to take up a volume consistent with their expected power dissipation. What is not intuitively clear is that there is an optimum core flux density, BOPT , where the total of copper and core losses will be a minimum. This BOPT will guide transformer and AC inductor design.

CIRCUIT DIAGRAM OF PROPOSED SYSTEM

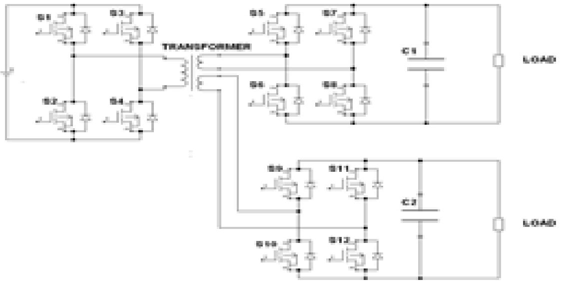


Figure : Circuit diagram of proposed system

The proposed system consist of three full bridges . Out of which one bridge act as an input bridge and the other two bridges acts as output bridge. Here FB1 and FB2 are the two output bridge and FB3 is the input bridge. The isolated transformer is the high frequency transformer.The active bridge consist of four IGBT switches and four free wheeling diode. Here IGBT act as the switches whereas the freewheeling diode conducts or freewheels the power back to the source.

ADVANTAGES

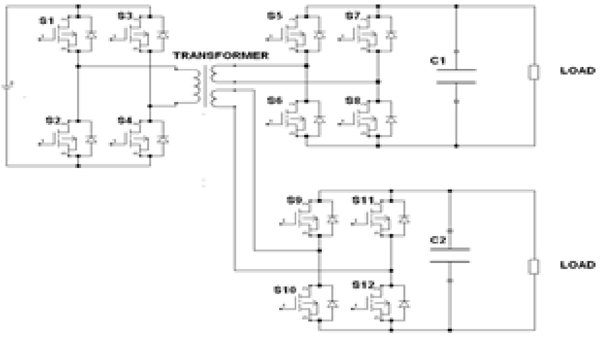
- Multiple outputs are possible
- Different levels of outputs are possible
- switch stress will be low.
- Easy to control
- Soft switching techniques are used.

APPLICATIONS

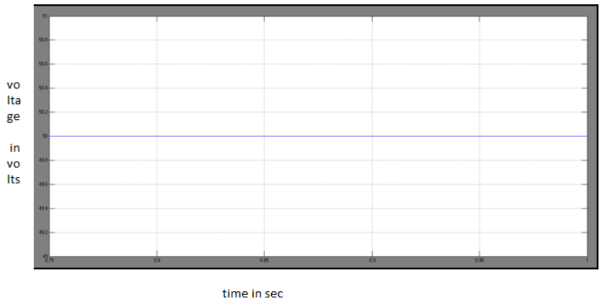
- HVDC transmission
- Grid connected systems
- Feeders in transmission line

IV. RESULTS

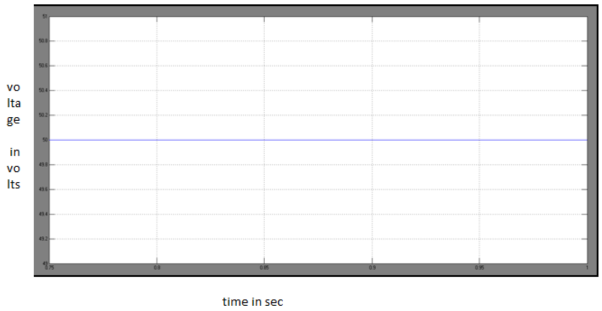
SIMULATION DIAGRAM



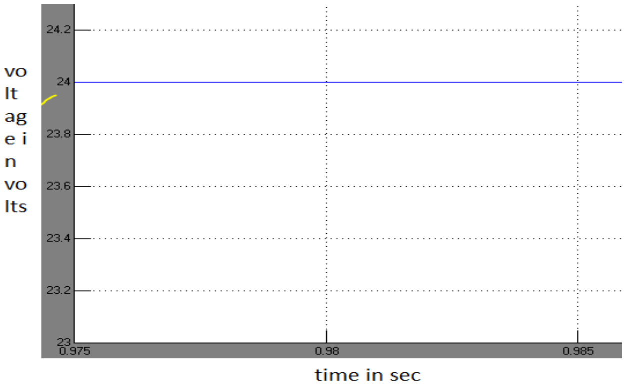
INTPUT OF THE EXISTING SYSTEM



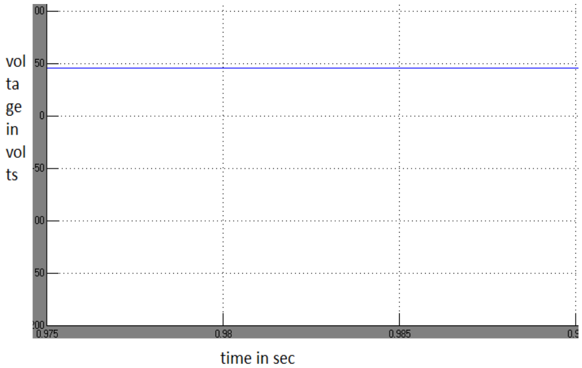
OUTPUT

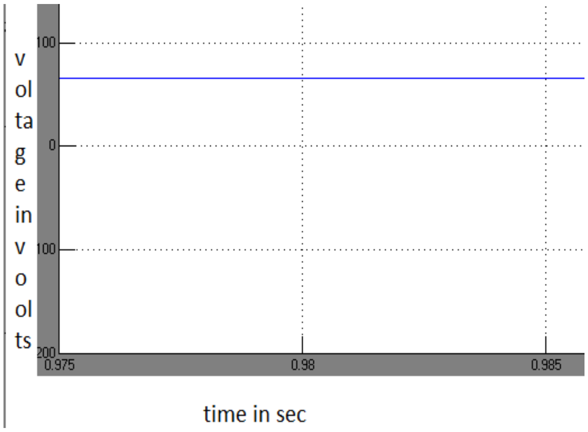


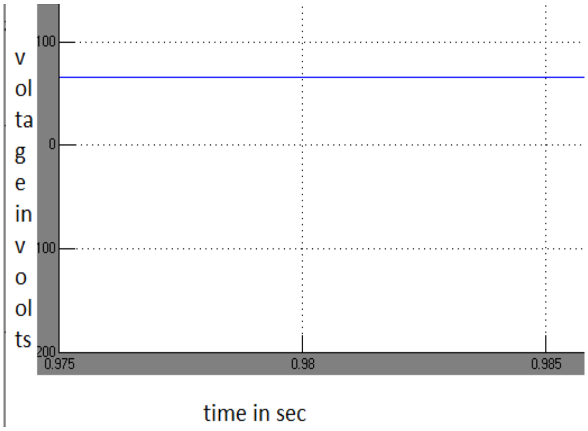
INPUT OF SYSTEM WITH FILTER

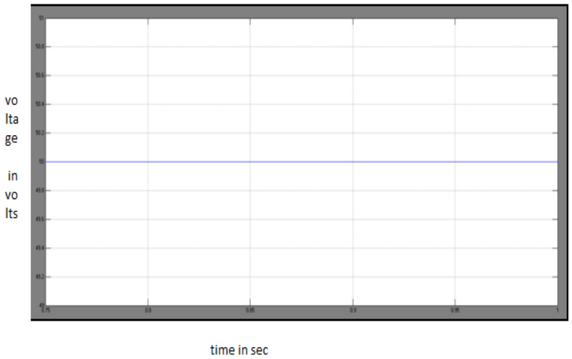


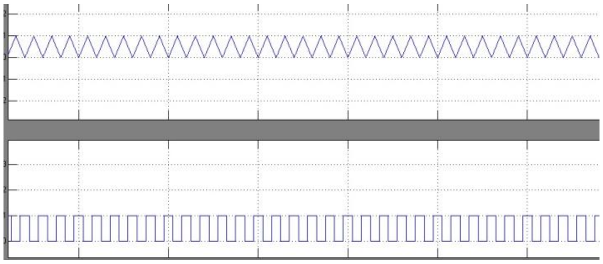
OUTPUT OF FULL BRIDGE 2

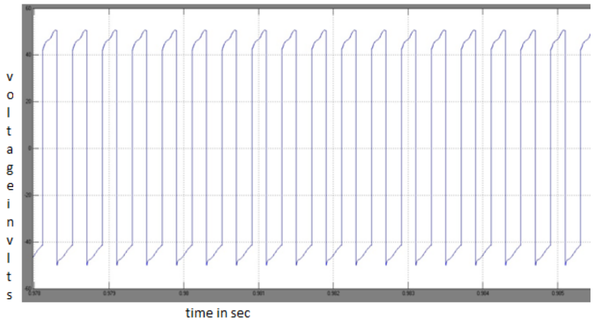












V. CONCLUSION

In this work, a dual active bridge is identified as a preferred power converter for interfacing the low voltage and high voltage dc busses of the Smart Green Power Node system due to its potential high power capacity and bidirectional power flow capabilities. An overview of the dual active bridge converter principle of operation, bidirectional power flow capability, and dynamic characteristics were discussed in Chapter 3. Converter modeling and control methods are developed in Chapter 4 based upon an enhanced Fourier series based model of the switching actions of the converter. Chapter 4 also demonstrates the feasibility and desirable results of applying a PI controller for matched steady state tracking of a reference output voltage. In conjunction with the feed forward control path, this control scheme facilitates optimal converter operation and performance, even accounting for load disturbances. Matlab / simulink simulations verify this control scheme's quality..

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