A Review on Bidirectional 'Dual – Active Bridge DC-DC Converter' for Various Applications.

N. Janaki[1], J. Suji Jenitha[2]

[1]*Assistant Professor,* [2]*PG Scholar*

[1,2]*Department Of Electrical And Electronics Engineering,*

[1,2]*Vels Institute Of Science Technology And Advanced Studies, Chennai, India*

[1]*janakinarayanan4@gmail.com,*[2]*sujijenitha@gmail.com*

Abstract

An elaborate study of 'bidirectional dual – active bridge (DAB) DC-DC converter' for various applications using different methodology are briefly discussed in this paper. This paper reviews about the basic study of 'bidirectional dual-active bridge (DAB) DC-DC converter' for various applications and compares the advantages of different applications. This involves in taking proper decision of the power flow, switching losses, Efficiency so that the selection of methodology will give proper performance.

Keywords: *'Bi-directional dual-active bridge (DAB)', 'DC-DC converter', DAB methodology, Soft-switching, Battery Efficiency.*

1. Introduction

When both the load and the source are having same current source that is DC, then we should make use of DC-DC converter. The incoming DC voltage is converted to an AC voltage using the primary side of the converter and then it flows to the transformer. The converter which is present in the secondary side rectifies and creates a voltage (DC), which is then supplied to the load. both the sources in both the direction. If both the load and the source are DC, then we can use DC-DC converter. The 'bi-directional dual active bridge(DAB) DC-DC converter' is used most preferably, because the reason is that it have the ability to make the current flow in both the direction (forward and Reverse direction). The DAB DC-DC converters have the following advantages they are

1. Weightless.
2. Efficiency is high.
3. Size is compact.
4. Reliability is high.

1.1. Types Of Bridge Converters

There are two types of bridge converters. They are

1. Half bridge converter
2. Full bridge converter.

1.2. Half Bridge Converter

Half bridge converters have a single-phase leg which is parallel connected.it consist of two capacitors connected in each one phase of leg. Mostly this type of half bridge converter is used in isolated type 'bi-directional dual active (DAB) DC-DC converter' for various electric vehicle applications.

1.3. Full bridge converter

Full bridge converter consists of single and three phase 'H' bridge converters. most commonly used in all type of "isolated-bi- directional dual active DC-DC converters", and this is called as (DAB). DAB converters have high number of switches when compared to half bridge converters like 8,12 for single and three phases bridges

1.4. Types of "bi-directional DC-DC converters (BDC)"

There are two types of 'bi-directional DC-DC' converters. They are

1. Non–isolated (BDC) "bi-directional DC- DC converters".
2. Isolated-(BDC) "bidirectional DC-DC converters".

1.5. Non-isolated (BDC) bi-directional DC-DC converters

These converters are used when there is a small change in the voltage conversion. A common ground is shared by both input and output. Hence it cannot give protection to high electric voltages and also has more noise.

1.5.1 Types of "Non-isolated DC-DC voltage converters"

1. 'step-down converters' .
2. 'step-up converters' .
3. 'step-up/step-down converters'.
4. 'Inverting converters'.

"Step-down converter":
Step-down converter is used for generating a low output voltage than the input.

"Step-up converter":
This converter generates a higher output voltage than the input voltage. The polarities of both the input and the output remains same for the two converters.

"Buck-boost converter":
In this type the output voltage can either be increased or decreased than the input voltage. The polarity of the input get reversed in this type.

1.5.2. "Isolated-bidirectional DC-DC converters" (BDC):

In this type the converters have a separation between input and output terminals. This can be used for high voltage properties and also cut down the unwanted noise and allows to produce a clear DC source as output.

1.5.3. Types of "Isolated-bidirectional DC-DC converters"

1. 'Forward converters'
2. 'Fly back converters'
3. 'Push pull converters'
4. 'Resonant converters'
5. 'Half-bridge converters'
6. 'Full-bridge converters'

2. Study on 'DAB DC-DC Converters'

In the paper titled Optimizing Modeling of a "bidirectional dual active bridge DAB DC-DC converter" with frequency variation, the power flow in a 'bi-directional dual active bridge DC-DC converter' is approached by a novel modeling.

the mathematical solution is avoided for the modeling process of high frequency transformer currents for modulation types because of the basic superposition principles[9] This model is used as an optimization for converter losses of a 3.3 kW electric vehicle battery charger for a voltage of 400V and the voltage range of battery from 280V -420V phase-shift clamping intervals are commonly used as control variables, also the variation in the switching frequency is also considered for this optimization process. This optimal modulation including frequency variation increases the converter efficiency upto 8.6% for IGBTs and 17.8% for MOSFETs [9].

An other work titled High power "bi-directional dual active bridge DAB" and "double-dual active bridge DAB DC-DC converter" discusses about the 'double dual active bridge DC-DC converter'. In this, two separate 'dual active bridge' (DAB) is used which is very capable for high power load. Here IGBTs are used for handling high capacity current.[3]circuits which absorb energy are used to suppress the voltage spikes caused by circuit inductance when a switch is open, the commonly used snubber circuits are capacitor, resistor.[3] while coming to the result of this paper the voltage in output (boost) is 104.9V. Overall the best mode for operating is square wave mode and the snubbed capacitor across IGBTs reduces the device stresses, switching losses and improves converter performance.[3]

In the work"ZVS DC-DC converter for a three-phase bidirectional dual active bridge(DAB)" , three phase dual active bridge(TPDAB) is used and it transfers a bi-directional power flow of 12V and high voltage DC net[4].the converters are controlled by [PSM] 'phase shift modulation' with a fixed duty-cycle. when coming to the advantages and output result, (TPDAB) DC-DC converter has high efficiency and have large power handling capacity. (P=500W) and the net 12V was boosted up to 36V with an output voltage of 302V and switching frequency of 20KHZ.

According to the work titled To operate the "dual DC-DC converter dual active bridge (DAB)" in soft switching, the modulation strategy minimizes the converter losses. The main advantages are the converters conduction losses get reduced. Overall efficiency is increased by 20% by using the modulation strategy [2].as in same there are also two modes buck mode and the other one is boost mode. to overcome and eliminate the reactive power, and the dual active bridge DAB converter conduction losses, a novel shift control of dual phase is proposed [2] but it failed to operate the converter in all the operating range under soft switching with the conversion ratios for variable voltages are not analyzed.

3. "Bi-Directional Dual Active Bridge DAB DC-DC Converters" (BDC) Used In Various Applications

3.1 Photovoltaic Applications

By using both the 'renewable energy equipment and energy storage units' to give a stable and continuous power is called as "renewable energy co-generation system"[8]. In this renewable energy co-generation system, photo voltaic array and wind power units are used as the renewable energy units and the unit is also unidirectional DC-DC converters and after that the battery storage unit system played major role in the 'bi-directional DAB DC-DC (BDC) converters' .This 'bi-directional DAB DC-DC (BDC) converter' have many applications when compared to unidirectional DC-DC converters, they are high efficiency, handling large power, less switching losses, distributed power flow. In photovoltaic applications, it causes high energy circulation loss, high conduction losses, and low efficiency due to these drawbacks the switches has been reduced from eight to six. So that the complexity of the control scheme reached the level of suitability for high power and frequency.

So the transmission of power to the load is in unidirectional path and the energy which is circulating cannot flow back.

3.2 Applications of "Plug In Hybrid Electric Vehicle"

Another type of 'bi-directional DAB DC - DC converter' which is used in hybrid electric vehicle applications uses 4 (four) switches and 4 capacitors. This method has very high device stress of 2:1 voltage range.so to overcome this device stress in this type the converter is modified with a dc inductor that can minimize the stress devices and make it suitable for the "Plug In Hybrid Electric Vehicle" applications[6]. These converters can also operate for a source input voltage of wide ranges.

3.3 High Frequency Isolation

It reduces the volume and weight of the transformer. Mostly the single phase full bridge 'bi-directional dual active bridge' that is "(DAB DC-DC converter)" used in the hybrid electric vehicle and also in plug-in hybrid electric vehicle. These converters are often used in the electric vehicle for the application of vehicle to grid.The two full-bridges are connected to the two transformer windings and generates a square wave output voltage with a high frequency.

3.4"Three Phase Bidirectional Dual-Active Bridge (DAB) DC-DC Converter"

This type of 'bidirectional DAB DC-DC converter' operates on three phase bidirectional power flow of 12V[4].this type of three phase converters has many advantages, they are isolation features, small capacitance, smaller switch current stress, high power flow, efficiency is high.

3.5"Double Dual-Active Bridge (DDAB) DC-DC Converters For High power"

In this type of 'double dual active bridge (DAB) DC-DC converters', two separate 'dual-active bridge(DAB)' is used, which produces "high power load"[3]. Same in such a way to accommodate high DC- link voltages, more than 3000V, IGBTs (insulated gate bipolar transistors) have been used in common. Also IGBTs are used for handling high capacity current. So that 1-8 switches have been connected with antiparallel diodes and Snubber capacitors.

Snubber circuits are called as absorbing circuits that is 'energy absorbing circuits', it is used to suppress the spikes caused by the voltage which is caused by circuit inductance or leakage when a switch is open, the most commonly used snubber circuit is that a capacitor and a resistor is connected in series across the transistor. snubber capacitor connected along the IGBT reduces the "switching losses, device stress, and improves the performance of the converter"[3].

For handling low and high power load, separate dual active bridges (DAB) are used. For the high power dual active bridge, IGBTs are connected in parallel and have very high current in the range of hundred amperes and the voltages in the range of 6000V. While in the lower dual active bridge MOSFET is used, low voltage which is less than 200V is obtained.

3.6.Vehicle-to-Grid(V2G) Applications

The applications of the "dual active bridge (DAB) DC-DC converter" in 'vehicle to grid (V2G)' is briefly discussed in this paper[5].the scope of this paper is to model naturally commutated"bi- directional dual-active bridge(DAB) DC-DC converter" with open and closed loop system. Coming to the advantages less switching losses and gives high efficiency, stability[5]. Then the transformer size is

small. then the output result is that a bi- directional DC-DC (BDC) converter of 6KW for connecting to a bank of 360V battery and a 400V microrrede[5] have been the output for this paper. The applications are that it is used in battery operated electric vehicles, battery charging, DC micro grids.

4. Conclusion

This paper reviews about different types of "bidirectional dual-active bridge (DAB) DC-DC converter" for various applications. This paper discusses about the advantages, disadvantages, assumptions, applications, and the different methodology adopted. All types of 'dual active bridge (DAB) DC-DC converters' are analyzed and the performance of these converter plays a major role in handling power flow, efficiency and accuracy. Among all the DC-DC converters 'bi-directional dual active bridge (DAB) DC-DC converter' is preferred to improve overall efficiency, power flow and for fast response in electric vehicle applications and also in other applications.

References

[1] Bidirectional Dual-Active-Bridge DC-DC Converter with Triple-Phase-Shift Control H. Wen and W. Xiao Electrical Power Engineering MIST, Abu Dhabi, UAE ,2013.

[2] G. Oggier, Garci, x, G. O. a, and A. R. Oliva, "Modulation Strategy to Operate the Dual Active Bridge DC-DC Converter Under Soft Switching in the Whole Operating Range," Power Electronics, IEEE Transactions on, vol. 26, no. 4, pp. 1228-1236, 2011.

[3] High-Power Bidirectional Dual Active Bridge And Double Dual Active Bridge DC- DC Converter S.Venkatesh 1, K.Gopiteja2, D.Subba rao3 Assistant professor, Department of EEE , KKR & KSR institute of technology & sciences , Guntur, A.P, India International Research Journal of Engineering and Technology (IRJET) e- ISSN: 2395 -0056 Volume: 04 Issue: 06 |June -2017-ISSN: 2395-0072.

[4] A Three-phase Dual Active Bridge Bidirectional ZVS DC/DC Converter 2012 International Conference on Applied Physics and Industrial Engineering Zhang Xuan1,Huang Shenghua1,Ning Guoyun College of Electrical & Electronic Engineering, Huazhong University of Science and Technology,Wuhan, China Dayu Electrical Technology Co., Ltd, Xiaogan, China.

[5] Bidirectional Dual-Active-Bridge DC- DC Converter for Vehicle-to-Grid Applications in DC Microgrids Anderson Vieira Federal Institution of Science and Technology-IFCE Fernando Antunes Federal University of Ceará The - UFC.Luan Mazza Federal Institution of Science and Technology-IFCE Demercil Oliveira Jr. Federal University of Ceará The – UFC,2018.

[6] Bi-Directional DC/DC Converters for Plug-in Hybrid Electric Vehicle (PHEV) Applications Sangtaek Han and Deepak Divan School of Electrical and Computer Engineering, Georgia Institute of Technology 777 Atlantic Dr.Atlanta GA, 30332 USA 978-1-4244-1874-9/08/2008 IEEE.

[7] A dual active bridge dc-dc converter for application in a smart user network G. Barone, G. Brusco, A. Burgio, M. Motta, D. Menniti, A. Pinnarelli, N. Sorrentino University of Calabria Arcavacata di Rende, Italy,2014

[8] The Bidirectional Dual Active Bridge DC/DC Converter for Photovoltaic Application Wenlong JING Swinburne University of Technology researchgate.net/publication/325367915,2012.

[9] Generalized Modeling and Optimization of a Bidirectional Dual Active Bridge DC-DC Converter including Frequency Variation Felix Jauch, Jiirgen Biela Laboratory for High Power Electronic Systems, ETH Zurich,2014.

[10] C. D. Scott and R. E. Smalley, "Diagnostic Ultrasound: Principles and Instruments", Journal of Nanosci. Nanotechnology., vol. 3, no. 2, **(2003)**, pp. 75-80.