# Implementation of high-Power Bidirectional dc-dc Converter for Aerospace Applications

Sabarinadh.P<sup>1</sup>,Barnabas<sup>2</sup> and Paul glady.J<sup>3</sup>

<sup>1,2,3</sup>Electrical and Electronics Engineering , Sathyabama University, Jeppiaar nagar,Chennai,Tamilnadu, india

*Abstract*—This project "implementation of bidirectional dc-dc converter for aerospace applications" composed of a bi directional dc to dc converter which can operate in buck and boost modes. This will be useful in regenerative applications. This project presents simulation of the proposed bidirectional dc to dc converter in both operational modes. The proposed model can be used to predict the converter efficiency at any desired operating point. The new model can serve as an important teaching cum-research tool for Dual Active Bridge hardware design (devices and passive components selection), soft-switching-operating range estimation, and performance prediction at the design stage. The operation of the DAB dc-dc converter has been verified through extensive simulations. A Dual Active Bridge converter prototype was designed on the basis of the proposed model.

#### 1. INTRODUCTION

The Dual active bridge converter consist of two full bridge circuits connected through an isolation transformer and a coupling inductor L, which may be provided partly or entirely by transformer leakage inductance. The full-bridge on the left-hand-side is connected to the high voltage (HV) DC bus and the full-bridge on the right-hand-side is connected to low voltage (LV) ultra capacitors. Each bridge is controlled to generate a high-frequency square-wave voltage at its terminals. By incorporating an appropriate value of coupling inductance, the two square-waves can be suitably phaseshifted to control the power flow from one DC source to the other. An active bridge on either side of the transformer allows bidirectional power transfer. Power flows from the bridge generating the leading square-wave. The key operating waveforms of the converter during the charging mode, that is when power flows from the HV side to the LV ultra capacitor side.

In simple full bridge circuit the power flows from source to the load, but in this circuit the power flows from source to the load in forward operation this we can call as buck operation mode and in the next cycle the load can be operated as source. In this the circuit will operate as a boost converter which will improve the DC voltage by using isolation transformer and inductor which can be phase shifted. This circuit can operate in two types such as buck and boost operations. In forward operation one full bridge circuit operate as inverter to convert dc voltage into ac voltage and the other full bridge circuit operates as rectifier to convert ac voltage into dc voltage.

The bi-directional dc to dc converter means the input dc supply is converted into ac and then dc by using two full bridge circuits. In one operation one full bridge circuit operate as rectifier in other operation it will operate as inverter similarly the second full bridge circuit will operate as rectifier in one operation and in the reverse operation it will operate as inverter. Both the converters are always in operating in rectifier mode or inverter mode so we can call as dual active bridge and also the operation continues in both forward and reverse mode then we completely call as Bidirectional dual active bridge (DAB) dc-dc converter.

Bidirectional power flow capability is a key feature of DAB dc-dc converters, permitting flexible interfacing to energy storage devices. Although the DAB converter has an inherent soft-switching attribute, it is limited to a reduced operating range depending on voltage conversion ratio and output current. This is a drawback for applications that operate mainly with variable or low loads as the overall converter efficiency is reduced. Recently, a model was proposed for the DAB converter that has been validated under certain operating conditions for low load, low efficiency, and low-power operation, but the device average and rms current models and transformer/inductor RMS current models which could serve useful for hardware design were not proposed. Moreover, such current models are not available in the existing literature for either low-power or high-power converter operation. A comparative evaluation of single- and three-phase versions of the DAB converter was performed in from the perspective of operating performance and losses for bidirectional power conversion applications. The comparisons pave the way for a choice to be made between these two alternatives for any particular application. Inoue and Akagi validated DAB performance for next-generation power conversion systems using ultra capacitor-based technologies.

2. Basic Principle of Operation

Future aircraft are likely to employ electrically powered actuators for adjusting flight control surfaces and other high-power transient loads. To meet the peak power demands of aircraft electric loads and to absorb regenerated power, an ultra capacitor based energy storage system is examined in which a bidirectional DAB dc-dc converter is used. The DAB converter shown in Fig. 1 consists of two full-bridge circuits connected through an isolation transformer and a coupling inductor L, which may be provided partly or entirely by the transformer leakage inductance. The full bridge on the left hand side of Fig. 1 is connected to the HV dc bus and the full bridge on the right-hand side is connected to the lowvoltage (LV) ultra capacitor. Each bridge is controlled to generate an HF square-wave voltage at its terminals. By incorporating an appropriate value of coupling inductance, the two square-waves can be suitably phase shifted with respect to each other to control power flow from one dc source to another. Thus, bidirectional power flow is enabled through a small lightweight HF transformer and inductor combination, and power flows from the bridge generating the leading square-wave. Although various modes of operation of the DAB converter have been presented recently [20], [26], [28] for highpower operation, the square-wave mode is supposedly the best operatingmode. This is because imposing quasi-square-wave on the transformer primary and secondary voltages results in trapezoidal, triangular, and sinusoidal waveforms of inductor current in the DAB converter ac link. These modes are beneficial for extending the low-power operating range of the converter [26]. Although these modes tend to reduce the switching losses, the voltage loss is significant due to zero voltage periods in the quasisquare-wave, which reduces the effective power transfer at high-power levels. Therefore, the contribution highlighted in this paper forms important research on the DAB converter.



fig. 1 bi-directional dual active bridge circuit diagram

Initially the supply is given to the input terminal Vin, the supply is dc supply is flows through the MOSFETS, and an isolation transformer is connected to the other full bridge converter which is having four MOSFETS and capacitors connected across each switch, two capacitors are connected across input supply and output terminal to provide better ripple free operation. This circuit can operate in two types such as buck and boost operations. In forward operation one full bridge circuit operate as inverter to convert dc voltage into ac voltage and the other full bridge circuit operates as rectifier to convert ac voltage into dc voltage.

The bi-directional dc to dc converter means the input dc supply is converted into ac and then dc by using two full bridge circuits. In one operation one full bridge circuit operate as rectifier in other operation it will operate as inverter similarly the second full bridge circuit will operate as rectifier in one operation and in the reverse operation it will operate as inverter. Both the converters are always in operating in rectifier mode or inverter mode so we can call as dual active bridge and also the operation continues in both forward and reverse mode then we completely call as Bi-directional dual active bridge (DAB) dc-dc converter.

#### 2.1 SOFTSWICHING TECHNIQUE

#### A.ZVS LIMITS:

During transistor turn-OFF, resonance will naturally occur between device output capacitance and coupling inductance. The energy stored in the coupling inductance is sufficient to ensure charge/discharge of device output capacitances at the switching instants. The converter operating conditions to achieve virtually

Loss-less ZVS conditions are:

• At turn-ON of any device, its anti parallel diode is conducting

• At turn-OFF of any device, the minimum current flow through the device is positive.

In practice, the ZVS limits will be slightly different due to the requirement for inductor current to be sufficient to ensure charge/discharge of the device output capacitances at the switching instants.

## 2.2 .SIMULATION OF PROPOSED CIRCUIT A.BUCK MODE-FORWARD MODE



#### fig. 2 simulation of proposed circuit buck mode operation

The above figure shows the simulation circuit of proposed circuit in buck mode of operation. In this proposed circuit using MOSFETS, capacitors, an isolation transformer, inductor and resistive load are available. The snubber inductor is connected in series with the isolation transformer. The gating pulses are given to these MOSFETs to turn-on. The dc voltage applied at input flows through the circuit as explained earlier. However the voltage applied at the input terminal the circuit bucks the input voltage to lower level. The input and output voltage waveforms are shown below.

#### INPUT WAVEFORM



fig.3 input voltage waveform of proposed circuit The above figure shows the input voltage applied to the proposed circuit in buck mode of operation. The input dc voltage is 12v. The dc voltage waveform can be attained by using scope.



fig.4 input current waveform of proposed circuit

#### OUTPUT WAVEFORMS



fig.5 output voltage waveform of proposed circuit

The above figure shows the output voltage waveform of the proposed circuit in buck mode of operation. By applying 9v dc as input voltage the output voltage can be attained across capacitors is 2.147 dc.

#### **B.BOOST MODE-REVERSE MODE**



fig. 6 simulation of proposed circuit reverses operation

The above figure shows the simulation circuit of proposed circuit in boost mode of operation. In this proposed circuit using MOSFETS, capacitors, an isolation transformer, inductor and resistive load are available. The snubber inductor is connected in series with the isolation transformer. The load in forward direction or in buck operation acts as an input source. The gating pulses are given to these MOSFETs to turn-on. The dc voltage applied at input flows through the circuit as explained earlier. However the voltage applied at the input terminal the circuit bucks the input voltage to lower level. The input and output voltage waveforms are shown below.



#### INPUT WAVEFORMS

fig.7 input voltage waveform

The above figure shows the input voltage applied to the proposed circuit in boost mode of operation. The input dc voltage is 6.5v. The dc voltage waveform can be attained by using scope.



fig 9 output voltage waveform

The above figure shows the output voltage waveform of the proposed circuit in boost mode of operation. By applying 6.5v dc as input voltage the output voltage can be attained across capacitors is 12.54vdc.



3. HARDWARE: fig 10hardware prototype

A. hardware results in buck mode



fig 11 input voltage in buck mode



fig 12 output voltage in buck mode

B. hardware results in buck mode



fig 13 input voltage in boost mode



fig 14 output voltage in boost mode

#### 4.CONCLUSION

This paper has presented a new steady-state model for the DAB converter. The square-wave operating mode of DAB is the best mode for high-power transfer. The operation of the DAB dc–dc converter has been verified through extensive simulations which in turn, confirm the accuracy of the model. The experimental results confirm that provision of snubber capacitors across the IGBTs reduces switching losses and device stresses and improves the converter performance. The simulation and experimental results are in good agreement demonstrating the effectiveness of the steady-state model. Therefore, the proposed model can serve as an important teaching-cum-research tool for DAB hardware design, softswitching-operating range estimation, and performance prediction at the design stage.

#### REFERENCES

- [1] B. Srimoolanathan, "Aircraft electrical power systems—Charged with opportunities," Aerospace and Defense Executive Briefing of Frost & Sullivan, Frost & Sullivan, Mountain View, CA, Nov. 2008.
  - Peter Fairley, The Smarter Grid, "Direct current networks gain ground," *Energy IEEE Spectr.*, Jan. 25, 2011.
  - [3] M. N. Kheraluwala, R. W. Gascoigne, D. M. Divan, and E. D. Baumann, "Performance characterization of a high-power dual active bridge DC-to-DC converter," *IEEE Trans. Ind. Appl.*, vol. 28, no. 6, pp. 1294–1301, Dec. 1992.
  - J K. Vangen, T. Melaa, A. K. Adnanes, and P. E. Kristiansen, "Dual active bridge converter with large soft-switching range," in *Proc. Eur. Conf. Power Electron. Appl.*, 1993, vol. 3, pp. 328–333.
  - [5] R. Steigerwald, R. DeDonker, and M. Kheraluwala, "A comparison of high-power dc-dc soft-switched converter topologies," *IEEE Trans. Ind. Appl.*, vol. 32, no. 5, pp. 1139–1145, Sep. 1996.
- 5] J. M. Zhang, D. M. Xu, and Z. Qian, "An improved dual active bridge DC/DC converter," in *Proc. IEEE Power Electron. Spec. Conf.*, Jun. 2001,vol. 1, pp. 232–236.
- [7] J. Walter and R. W. De Doncker, "High-power galvanically isolated DC/DC converter topology for future automobiles," in *Proc. IEEE Power Electron. Spec. Conf.*, Jun. 2003, pp. 27–32.
- [8] F. Krismer, J. Biela, and J. W. Kolar, "A comparative evaluation of Isolated bi-directional DC/DC converters with wide input and output Voltage range," in *Proc. IEEE Ind. Appl. Conf.*, Oct. 2005, pp. 599– 606.
- 9] F. Krismer, S. Round, and J. W. Kolar, "Performance optimization of a high current dual active bridge with a wide operating voltage range," in *Proc. IEEE Power Electron. Spec. Conf.*, Jun., 2006, pp. 1–7.
- [10] G.-J. Su and L. Tang, "A three-phase bidirectional DC-DC converter for automotive applications," in *Proc. IEEE Ind. Appl. Soc. Annu.Meet.*, Oct.2008, pp. 1–7.
- S. Zhiyu, R. Burgos, D. Boroyevich, and F. Wang, "Soft-switching Capability analysis of a dual active bridge dc-dc converter," in *Proc. IEEE Electr. Ship Technol. Symp.*, 2009, pp. 334–339.
- 2] E. Hiraki, K. Yamamoto, T. Tanaka, and T. Mishima, "An isolated Bidirectional DC-DC soft switching converter for super capacitor based Energy storage systems," in *Proc. IEEE Power Electron. Spec. Conf.*, Jun. 2007,pp. 390–395.
- [3]M. H. Kheraluwala, D. W. Novotny, and D. M. Divan, "Design Considerations for high power high frequency transformers," in *Proc. IEEE Power Electron. Spec. Conf.*, Jun. 1990, pp. 734–742.
- [14] M. H. Kheraluwala, D. W. Novotny, and D. M. Divan, "Coaxially wound transformers for high-power high-frequency applications," *IEEE Trans.Power Electron.*, vol. 7, no. 1, pp. 54–62, Jan. 1992.
- [15] A. K. Jain and R. Ayyanar, "PWM control of dual active bridge: Comprehensive analysis and experimental verification," *IEEE Trans.*

### **WWW.ijreat.org** Published by: PIONEER RESEARCH & DEVELOPMENT GROUP(www.prdg.org)

#### IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 1, Issue 1, March, 2013 ISSN: 2320 - 8791 www.ijreat.org

Power Electron., vol. 26, no. 4, pp. 1215–1227, Apr. 2011.

- [16] S. J. Cutts, "Acollaborative approach to themore electric aircraft," in Proc IEE Int. Conf. Power Electron., Mach. Drives, Jun. 2002, pp. 223-228.
- [17] H. Zhou and A. M. Khambadkone, "Hybrid modulation for dual active bridge bi-directional converter with extended power range for ultracapacitor application," IEEE Trans. Ind. Appl., vol. 45, no. 4, pp. 1434–1442,Jul. 2009.
- [18] S. Inoue and H. Akagi, "A bidirectional isolated dc-dc converter as a core circuit of the next-generation medium-voltage power conversionsystem,' IEEE Trans. Power Electron., vol. 22, no. 2, pp. 535-542, Mar. 2007.
- [19] G. G. Oggier, G. O. Garcia, and A. R. Oliva, "Modulation strategy to operate the dual active bridge DC-DC converter under soft switching in the whole operating range," IEEE Trans. Power Electron., vol. 26, no. 4,pp. 1228–1236, Apr. 2011.
  [20] F. Krismer and J. W. Kolar, "Accurate power loss model derivation of a
- high-current dual active bridge converter for an automotive application" IEEE Trans. Ind. Electron., vol. 57, no. 3, pp. 881-891, Mar. 2010.
- [21] M. H. Kheraluwala, D. W. Novotny, and D. M. Divan, "Design considerations for high power high frequency transformers," in Proc. IEEE Power Electron. Spec. Conf., Jun. 1990, pp. 734-742.

