

Bidirectional DC-DC Converter with High Frequency Isolation for V2G Applications

Vítor Sobrado¹, Adriano Carvalho², António Martins³, Abel Ferreira⁴ and Filipe Pereira⁵

Abstract—This paper presents the topological solution of dual active bridge (DAB) with phase shift control for a bidirectional DC-DC converter. This converter typically integrates systems for vehicle to grid (V2G) and vehicle to grid (G2V) applications. About DAB topology are illustrated the key aspects of its operation also the condition of zero voltage switch (ZVS). Experimental results allow to validate their correct operation in applications of V2G and G2V, bidirectional transit of energy.

Index Terms— Dual active bridge, bidirectional DC-DC converter, vehicle to grid, high frequency isolation.

I. INTRODUCTION

THE increase in the number of plug-in electric vehicles along with the need for greater incursion of power into the grid from renewable sources, due to environmental, economic and policy issues, has promoted the use of such vehicles as energy buffers between the network and the final user[1]. Such use comprises two phases, charging and discharging of the vehicle battery, G2V and V2G respectively.

Grid connection of electric vehicles requires typically a DC-DC converter that allows connecting vehicles with high voltage (HV) batteries with different AC and DC voltage levels.

DC-DC converters based on the DAB topology, Fig. 1, are presented as strong candidates for G2V and V2G applications, because they enable the bidirectional transfer of energy, have great energy efficiency and galvanic isolation[2].

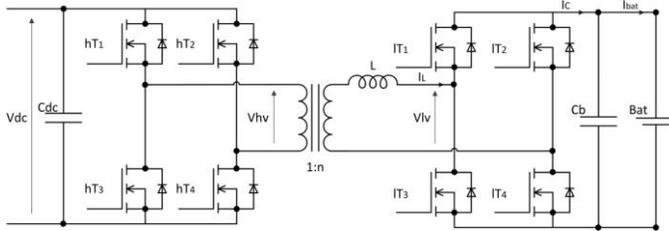


Fig. 1. Schematic of the DAB DC-DC converter.

The greater efficiency of this topology is achieved by the isolation at high frequency and the inherent ZVS operation. The galvanic isolation of the high frequency stage allows

reducing the volume and weight of the transformer; this characteristic is particularly interesting in on-board systems.

II. PRINCIPLE OF OPERATION

The DAB converter, as shown in Fig. 1, consists of two full bridges connected via a transformer and a coupling inductor. Each bridge is connected to a DC bus of low and high voltage respectively. Each bridge is controlled in order to generate a square wave with high frequency at the AC terminals. This is the best method for high power applications[3]. The bidirectional energy flow is possible due to transformer and coupling inductor, and flows from the bridge generating the leading square-wave.

Fig. 2 illustrates the key waveforms of this topology, i.e., when power flows from the HV to LV side.

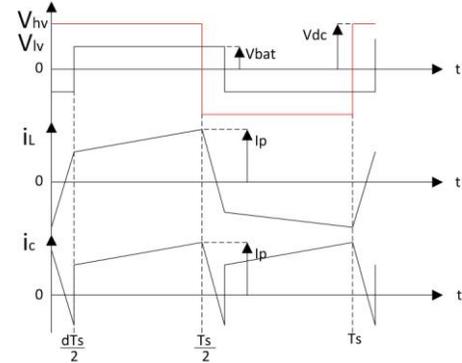


Fig. 2. Key waveforms of the DAB topology when power flows from the HV to LV side.

III. PROTOTYPE DESIGN

A. Transformer considerations

The design of a high frequency transformer, include several requirements including appropriate choice of ferrite and considerations due to skin effect. In this paper is given special attention on transformer turns ratio since it determines the limits of operation ZVS converters DAB. This ratio should be the same as the voltages between the high and low buses, in order to get a current control in the entire range without leaving the ZVS condition. The equation 1 shows the condition to satisfy ZVS[3]. Once the voltage on low voltage bus, depends on the state of charge (SoC) of the battery and the battery in question, was taken into account a typical value of batteries in electric vehicles, 300V, so the transformation ratio selected is 4:3.

¹ vitors@fe.up.pt.

² asc@fe.up.pt.

³ ajm@fe.up.pt.

⁴ abelf@fe.up.pt.

⁵ filipep@fe.up.pt.

$$d \geq 0,5 - \frac{V'_{bat}}{2} \quad (1)$$

Where is $V'_{bat} = \frac{V_{bat}}{nV_{dc}}$

B. Design of the coupling inductor

With equation 2 derived, from a powerless model of this type of converter[3] it is possible to design the inductor according to the other system parameters, which are imposed by the requirements listed in Table I.

$$L = \frac{T_s}{4I_p} [nV_{dc} + V_{bat}(2d_n - 1)] \quad (2)$$

TABLE I
SYSTEM PARAMETERS

Symbol	Parameter	Rating
I_p	peak current in the inductor	25A
T_s	switching period of the transistors iTx	100 μ s
n	transformer turns ratio	4:3
V_{dc}	DC bus voltage	400V
V_{bat}	rated battery voltage	300V
d_n	rated duty ratio	0.5

Therefore the value of the coupling inductance L, is 300 μ H.

C. Prototype

Is show in Fig. 3 the laboratory workbench with the assembled prototype. The current control by phase shift was implemented in the Texas Instruments DSP microprocessor TMS320F28335[4].

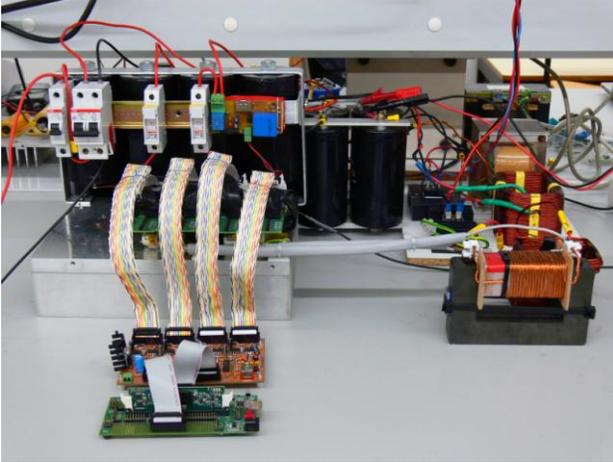


Fig. 3. Laboratory workbench with the assembled prototype.

D. Implementation results

Fig. 4 shows the dynamic test in which it is imposed a variable duty ratio between 0 and 0.37, in order to cause a pulsating energy transfer from the higher voltage bus to the lowest.

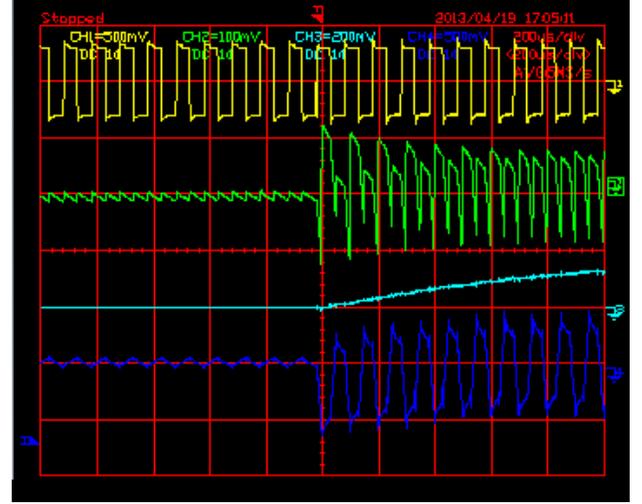


Fig. 4. Dynamic test with variable duty ratio. Vh (Ch1- yellow: 100V/div), Ic (Ch2- green: 5A/div), Ibat (Ch3- cyan: 2A/div), Vh (Ch4- blue: 5A/div).

This test was performed at a voltage of 60V and 50V on high and low voltage sides respectively and shows the prototype performance.

IV. CONCLUSION

This paper presents the key aspects about the operation and implementation of a DC-DC converter based on DAB topology with a phase shift control for V2G and G2V applications. Laboratory tests show its good functioning in dynamic regimen with bidirectional transfer of energy, essential condition in V2G and G2V applications.

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