Realization of a Compact Bidirectional Unregulated Level Converter for Battery to Battery (B2B) Energy Conversion System

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Abstracts:

A compact bidirectional unregulated level converter (BULC) for battery to battery (B2B) energy conversion system is discussed in this paper. With this converter topology, step-up and step-down modes can be realized with high efficiency easily. In step-up mode, the topology acts as a voltage-doubler to achieve 48V to 96V B2B energy conversion. In step-down mode, the converter acts as a voltage-divider to achieve 96V to 48V B2B energy conversion. Experimental results are made to verify the performance of the proposed bidirectional ULC.

Description of the proposed converter system

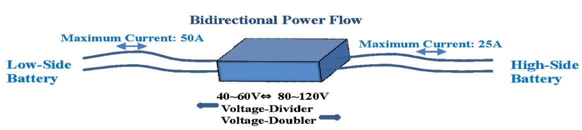


Fig. 1 The conceptual B2B energy conversion system

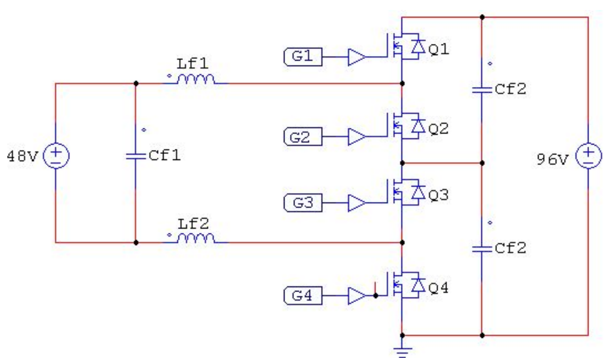
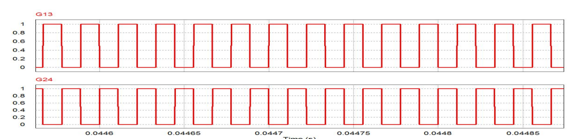


Fig. 2 The proposed BULC topology

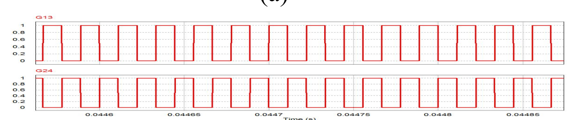
The automotive industry has benefited from permanent technological advances which have been increasing the need for more advanced power electronics devices. This increase in energy demand is due to the massive use of electronic systems which allows more comfort and flexibility. Thus, it will be unviable to maintain the 42V in automotive systems, due to the high current levels through the electronic devices. Therefore, 48V systems have been increasingly used in automotive applications. Besides, for fully micro electric vehicles (MEVs), the high voltage battery bank (96V) is used as a power source supplying the EV motor driver. Thus, a conceptual B2B energy conversion system could be used to supply energy for both 48 and 96V devices, as shown in Fig. 1 where it consists of low-side/high-side batteries and a high power converter with bidirectional power flow capability.

Operation principle of proposed converter

Fig. 2 shows the proposed BULC topology, and its driving signals with ideal 50% duty cycle for power switches as illustrated in Fig. 3. In the proposed BULC topology, it consists of four active power MOSFETs, a small high frequency filter L_{f1}-C_{f1}-L_{f2} is used not only to smooth the switching, but also to prevent the inrush current during starting transient condition.



(a)



(b)

Fig. 3 Driving signals of BULC (a) Q1 and Q3, (b) Q2 and Q4

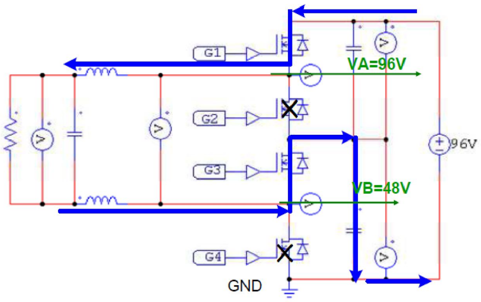
It can be seen that from Fig. 2, when the switches (MOSFETs with free- wheeling diodes) are turned on, the current can flow in either direction, so the topology is a bidirectional converter.

In steady-state, based on the driving signals, there are two switching states in step-down mode as illustrated in Fig. 4. In this mode, the current flow is draw from high-side power source to low-side load. When switches Q1 and Q3 are turned on, the low-side voltage can be derived as (1). The same results can be obtained when Q2 and Q4 are turned on.

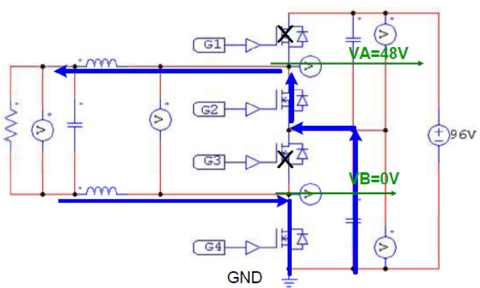
$$V_L=V_A-V_B=48\text{V (i.e. } V_L=0.5V_H) \quad (1)$$

Similarly, there are also two switching states in step-up mode as illustrated in Fig. 5. In this mode, the current flow is draw from low-side power source to high-side load. When switches Q1 and Q3 are turned on, the low-side voltage can be derived as (1). The same results can be obtained when Q2 and Q4 are turned on.

$$V_H=2(V_A-V_B)=96\text{V (i.e. } V_H=2V_L) \quad (2)$$

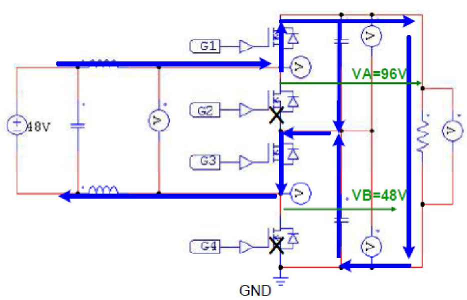


(a)

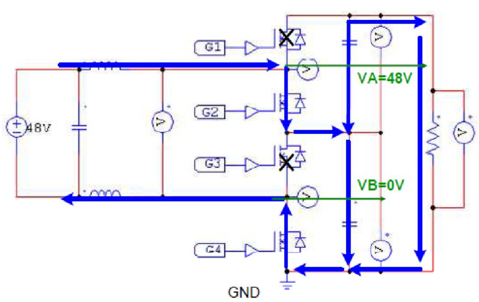


(b)

Fig. 4 Equivalent circuits in step-down mode



(a)



(b)

Fig. 5 Equivalent circuits in step-up mode

Results

To verify the concept, a 2kW BULC prototype is constructed as Fig. 6, and its waveforms are shown in Fig. 7~8. The maximum conversion efficiency of the converter is about 97%.

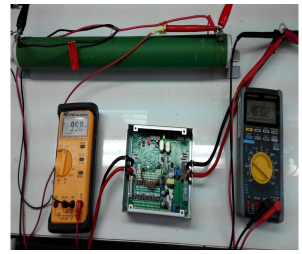


Fig. 6 Constructed 2kW BULC prototype

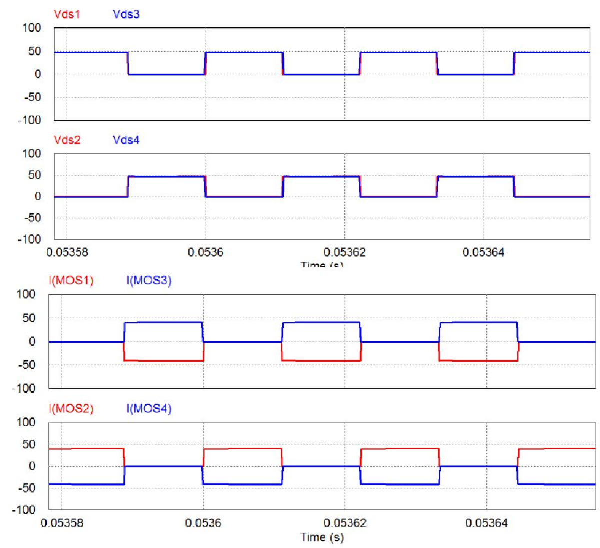


Fig. 7 Waveforms of voltage/current on all switches

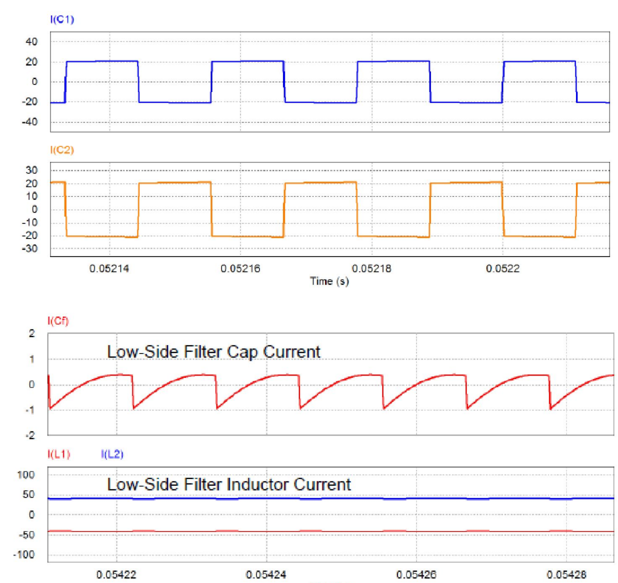


Fig. 8 Waveforms of the high frequency filter L_{f1}-C_{f1}-L_{f2}