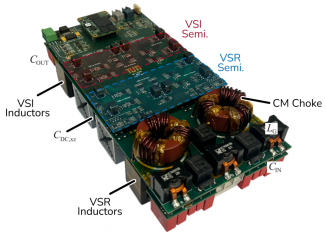
High-Efficiency Converter for Variable Speed Drives

Electric motors power industry automation, robotics, drilling, compressors, pumps, fans and many other machines. Whenever the load on the motor is changing with time, a Variable Speed Drive (VSD) is preferable due to its high operational efficiency and flexibility. If the motor is interfaced with a three-phase grid and requires bidirectional power flow, the VSD is commonly designed as a Voltage source Back-to-Back Converter (V-BBC). This invention further improves the efficiency of a V-BBC.



Switching losses reduced by more than 30 %

IP RIGHTS
European Application Filed
2025

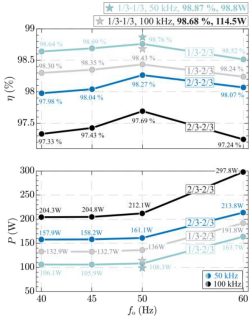
When implemented in a V-BBC hardware prototype, the invention leads to the significant efficiency increase and loss reduction shown in the graphs to the right. This offers the prospect of several advantages both in V-BBC-controlled motors and variable-speed electric generators such as wind turbines:

01 The increased conversion efficiency lowers energy costs or, in electric generators, increases the net electricity produced.

02 Strongly reduced power losses in the form of dissipated heat increase the lifetime of components.

03 Alternatively, cheaper components can be used or the converter can be designed to be more compact.

04 Conventional designs can be optimized according to the invention with minimal changes to the components.



Above: Efficiency and power loss for different output frequencies of a V-BBC with either both sides operating with conventional 2/3 DPWM or one side operating with 1/3 DPWM according to the invention. Grid frequency 50 Hz, switching frequency 50 or 100 kHz. Left: 11 kW hardware prototype producing the above data. Dimensions 280 × 132 × 63 mm³.

REFERENCES:

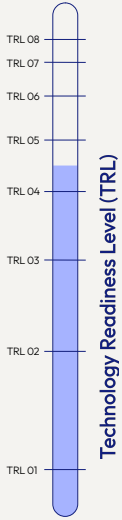
Leontaris, de Sousa & Heldwein, IEEE Trans. Pow. Electr. 2025, doi: 10.1109/TPEL.2025.3624327

CHALLENGE

The V-BBC enables bidirectional power flow at a high conversion efficiency with a rather simple topology of only 12 semiconductor switches. Thereby, the Voltage-Source Rectifier (VSR) facing the grid, and the Voltage-Source Inverter (VSI) driving the load are usually both run with a 2/3 discontinuous pulse-width modulation (DPWM), where the switches in two out of three legs of both the VSR and VSI are active at any given time and the DC-link voltage is fixed at a constant (high) value.

INNOVATION

The invention introduces a new form of switching pattern of the semiconductor switches of the V-BBC. As in the regular case, either the VSR or VSI runs with a 2/3 DPWM, with two legs switching and one leg clamped to one of the DC-link rails. However, on the other side of the V-BBC, only one leg is switching, while the remaining legs are clamped to the negative and positive rail of the DC link respectively. The voltage of the DC link follows the highest line voltage. This still allows for synthesizing AC currents in all phases while reducing the number of switching transitions, maintaining the minimum possible DC-link voltage, and thus minimizing the switching losses.



01 Basic principles observed · 02 Technology concept formulated · 03 Experimental proof of concept · 04 Technology validated in lab · 05 Technology validated in relevant environment · 06 Technology demonstrated in relevant environment · 07 System prototype demonstrated in operational environment · 08 System complete and qualified

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