Development of a 2 phase soft switching DC-DC Borgna converter

Degree programme: BSc in Electrical Engineering and Information Technology | Specialisation: Industrial Automation and Control
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A new topology of power converter, known as the Borgna converter, can operate with soft switching, more specifically zero voltage switching, which allows to reducing significantly the switching losses through the introduction of coupling capacitors and suitable modulation strategy.

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Motivation and goals

The goal is to design a converter capable of charging and discharging a battery to function as an energy storage system. The Borgna converter has been identified as a suitable candidate for this purpose due to its main advantage of operating with soft switching of semiconductor components, which minimizes switching losses. However, the control necessary for achieving soft switching results in high-frequency currents in passive components. To assess and quantify the potential gains considering this limitation, it was decided to compare the Borgna solution with a well-designed state-of-the-art converter. As part of this effort, a PCB converter prototype was developed to implement both the Borgna topology and the state-of-the-art interleaved converter.
In this study, we began with a theoretical circuit of the Borgna topology, which was tested in practice using laboratory components to verify its functionality. However, since laboratory components are both highly powerful and expensive, it is now necessary to determine whether implementing the topology with conventional components can still offer a significant advantage over a standard topology.

Realization

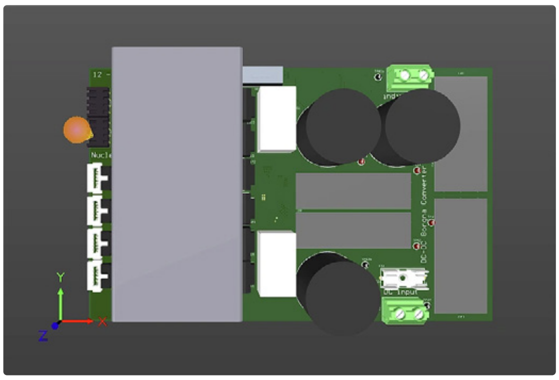
The work was divided into four main tasks:

- Simulation study of converter operation and loss analysis
- Preparation of the circuit schematic
- PCB design
- Validation and functional testing of the prototype

During the first phase, a detailed analysis of the converter's operation and its differences from other converter topologies, such as buck, boost, or buck-boost, was conducted. Various analyses of switching losses, conduction losses, and thermal losses were also performed using simulation software like LTspice and PLECS. The objective was to compare the differences between soft switching and hard switching and select the most suitable power semiconductors for the implemented topologies.
In the second phase, the circuit schematic was created, which involved choosing electronic components and determining their dimensions and calculations.
In the third phase, the PCB was designed. Special care was taken in this phase to maintain adequate isolation between various points of the circuit. When working with high voltages, such as 450V, it is crucial to ensure that the various components within the circuit are well-isolated to prevent damage.
In the fourth and final phase, the prototype was validated through a step-by-step testing process.
The circuit was tested to verify its functionality and performance.

Results and outlook

The provided picture showcases one of the project's outcomes, the PCB prototype. The testing and control of the prototype are conducted using a microcontroller system programmed in C. The microcontroller generates PWM signals to control the converter power semiconductors. While the prototype has been validated, further steps are required to fully validate its functionality and assess the efficiency of the implemented topologies. One important next step will be the implementation of a control application for charging and discharging batteries.



Final PCB