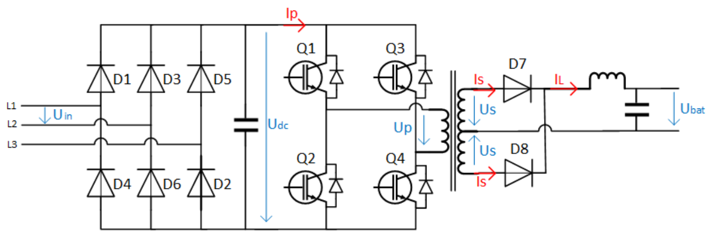
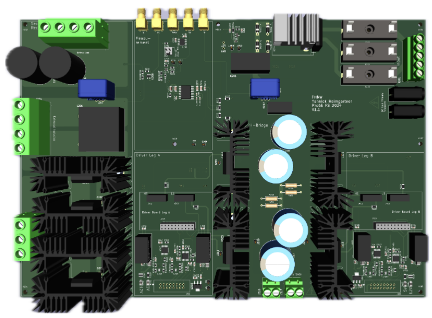
Feasibility analysis for an active rectifier

In this project, a prototype of a 1.2 kW battery charger for lead-acid batteries was developed, built, and tested. Using theoretical analyses, simulations, and the construction of the prototype, the goal was to create the foundation for a market-ready product that meets the specifications set by KriyaTarang GmbH.



Power electronic topology



PCB Design

Task

The goal of this project is to develop, build, and test a prototype of a 1.2 kW battery charger based on IGBTs. Building on the findings from a previous project and considering the defined system requirements, the system is designed to simultaneously charge multiple 24V lead-acid batteries with a charging current of 50 A. It will be connected to a three-phase 3x400 V, 50 Hz grid. In a previous project, various circuit topologies were analyzed and compared, focusing on power losses, costs, reliability, and size. After a detailed evaluation, the most promising topology was selected, built, and thoroughly examined. Plexim simulations were used to validate the overall behavior of the circuit.

Solution

The inverter consists of a diode bridge combined with an IGBT-based H-bridge, which generates a rectangular AC voltage at 20 kHz. The transformer provides galvanic isolation and converts the input voltage to the required output level. The output rectifier uses diodes and an LC filter to produce a smooth DC output. The control of the output voltage and current is based on the "Phase-Shift Switching" method. In this process, the IGBTs are controlled with PWM signals, always inserting a freewheeling state between power transfer states. The output voltage or current are regulated by adjusting the time ratio of these states, with the phase shift of the PWM signals ensuring accurate control.

Result

The PLECS simulation closely matches the lab results, confirming that the circuit functions correctly with the applied control system. However, the passive cooling provided by the current heatsink is insufficient for the rated power, so using a fan is recommended to improve cooling performance. Alternatively, an optimized layout could enhance natural convection, which would improve cooling efficiency, particularly at higher temperatures. In the lab tests, the prototype achieved an efficiency of approximately 87 %, while the power factor without a grid filter was 0.52. Further improvements to the cooling system or layout may help in achieving better overall performance.

Specifications and results

Power output:	1.2 kW
Nominal output voltage:	24 V DC
Nominal output current:	50 A
Input voltage (Grid):	3x400 V AC
Switching frequency:	20 kHz
Efficiency:	87 %
Power factor (without grid filter):	0.52

Project Team:
Yannick Heimgartner

Client:
KriyaTarang GmbH, Laufenburg

Coaches:
Prof. Dr. Ishan Pendharkar,
Tobias Strittmatter