Lucerne University of
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LUZERN

Technik & Architektur
FH Zentralschweiz

MSE | MASTER OF SCIENCE IN ENGINEERING

Master-Thesis Engineering, Fachgebiet Industrial Technologies

Development of a Fast DC Link Charger for Beam Wire-Scanners

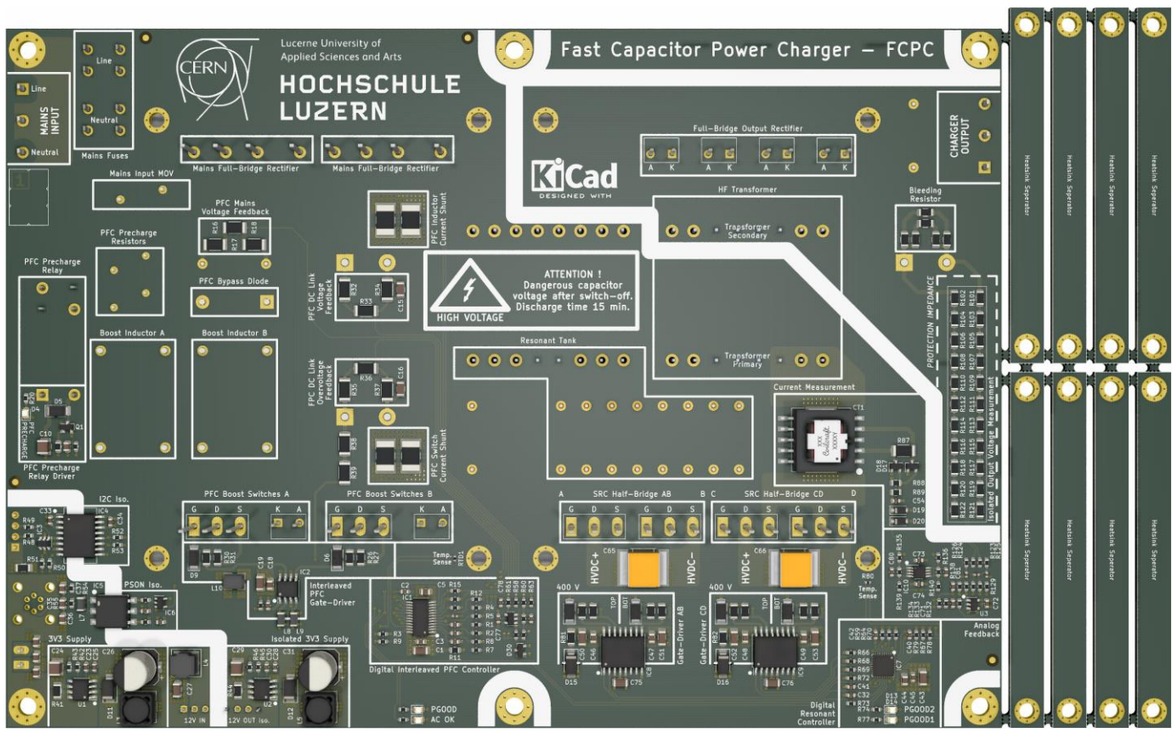

Figure 1: Top side of the developed fast DC link charger.

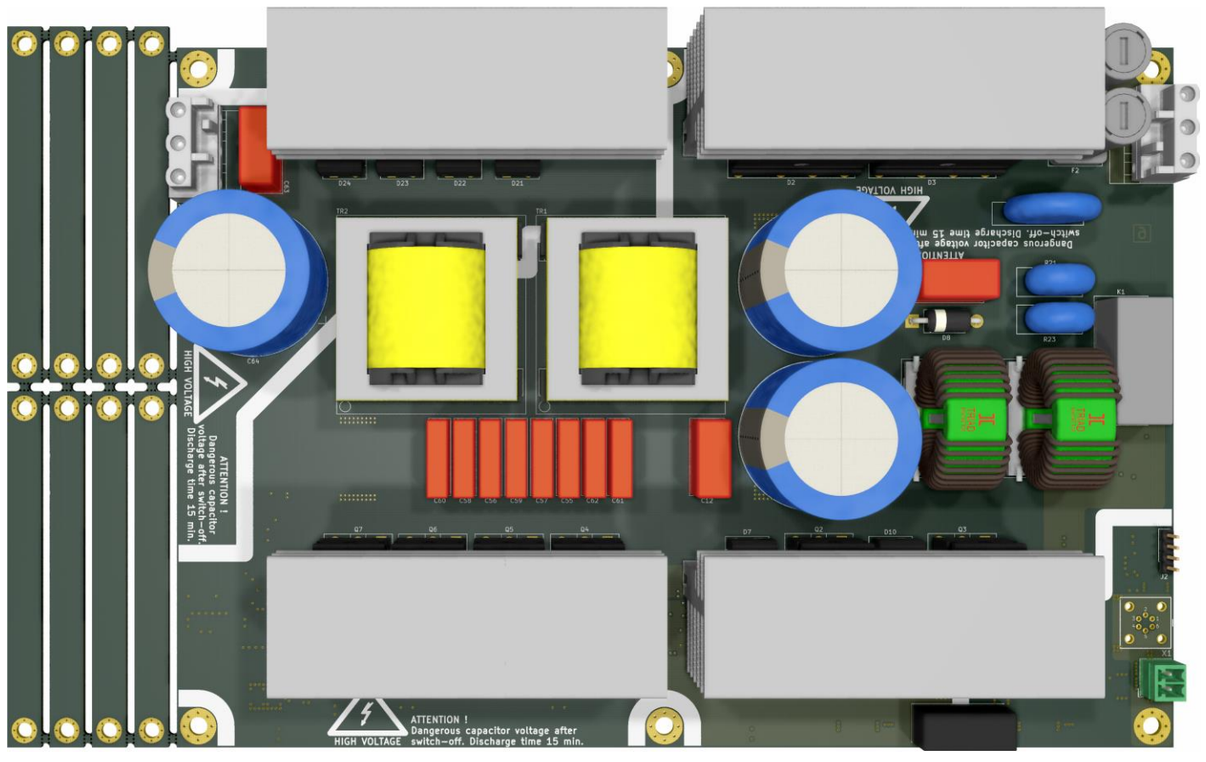

Figure 2: Bottom side of the developed fast DC link charger.

Table 1: Performance comparison of the proposed fast DC link charger.

parameter	conditions	DC link charger	
		existing	proposed
charge current, avg.	16 mF, 0 V to 400 V	0.107 A	1.904 A
charge rate, max.	16 mF, 400 V	48.9 J/s	762 J/s
repetition rate	16 mF, 400 V, 461 J	0.08 Hz	1.49 Hz
scanning rate	16 mF; 400 V, 461 J	0.1 scans/bp	1 scans/bp
startup time	16 mF, 0 V to 400 V	60 s	3.36 s
recharge time	16 mF, 320 V to 400 V	12 s	672 ms
BOM cost	10 to 50 units	520 CHF	428 CHF

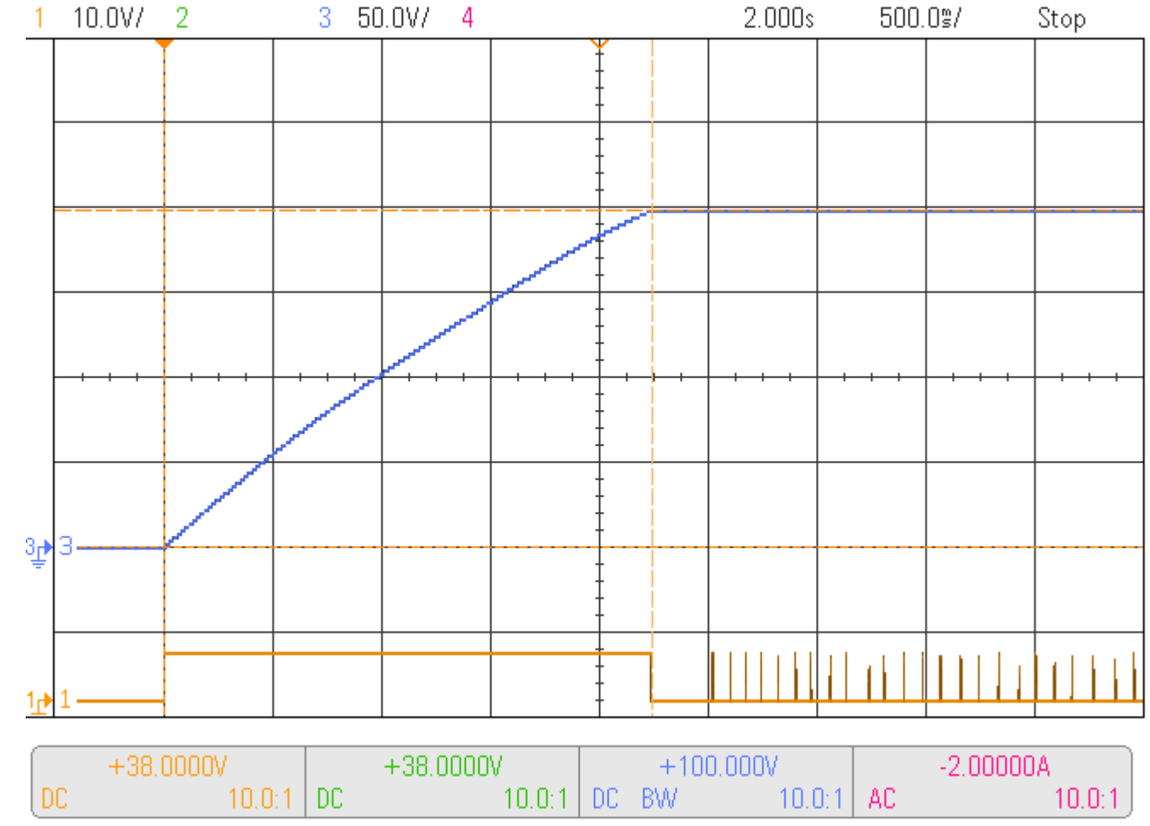

Figure 3: DC link startup. The figure shows the measurement result for the DC link startup with V_{in} = 190 V. The realized prototype charges a 10.47 mF DC link in 2.24 seconds from 0 V to 200 V (CH3, DC link voltage). After the set level of 200 V is reached, the controller uses a burst-mode operation to hold the DC link charged (CH1, charger modulation).

Problem

CERN has developed a new high-speed Beam Wire-Scanner (BWS) to measure the transverse beam profile of the LHC chain with wire speeds up to 20 m/s. The high-speed operation of the BWS leads to a highly pulsed loading of the motor drive. The drive inverter is supported by a 16 mF DC link with a working voltage up to 400 V.

The existing DC link charger is slow and requires a startup time of 60 s and a recharge time of 12 s. The slow charging of the motor drive DC link limits the repetition rate of the BWS. Further, the DC link charger is not configurable for the specific accelerator (PSB, PS, SPS, LHC) and requires hardware manipulation.

To improve the performance of the BWS, a new fast DC link charger is required supporting software configuration and high repetition rates.

Solution

A new fast DC link charger is developed to support remote control, software configuration, and high repetition rates for CERN's new high-speed BWS.

The proposed design is based on a two-stage converter architecture. The first stage is a single-phase 1 kW interleaved boost PFC converter for the mains supply. The second stage is an 800 W isolated series resonant converter (SRC) operated in even discontinuous conduction mode for the DC link charging. Both stages are implemented with digital controllers and enable remote control, software configuration, and real-time monitoring.

The proposed design of the fast DC link charger is highly configurable, eliminates the need for hardware variants for the complete LHC injector chain, and can be implemented with similar or lower costs.

Results

The proposed design is validated using PLECS simulations and verified with a real prototype.

The experimental results show that the startup time of BWS is reduced from 60s to 3.36 s and the recharge time is reduced from 12 s to 672 ms.

Outlook

The proposed design of the fast DC link charger allows the BWS to follow the rate of the Proton Synchrotron Booster (PSB) accelerator basic period of 1.2 s. The fast startup and the basic period operation allows the operators to unfold the full potential of the new high-speed BWS. The proposed upgrade is expected to have a relevant impact for future upgrades of the LHC complex, such as CERN's High-Luminosity Project (HL-LHC).

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