VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Hakan Polat**

The public defense will take place on **Monday 22nd December 2025 at 5 pm** in room **D.2.01** (Building D, VUB Main Campus)

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MODULAR WBG-POWER ELECTRONICS INTERFACE AND CONTROL SYSTEM FOR HIGH-POWER EV-CHARGERS AND LOCAL ENERGY STORAGE SYSTEMS

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Abstract of the PhD research

With the transition to vehicle electrification, the majority of electric vehicles uses 400V batteries. This voltage level has been selected carefully over the years, however some companies are shifting towards 800V structures to reduce the current in the electric drives and hence increase the overall efficiency. While it is expected that more cars will join the 800V trend, 400V is not expected to diminish in the close future due to additional isolation problems. Therefore, it is clear that off-board chargers in the future require a wide range of output voltage to maximize revenue and user-friendliness.

Transition to renewable energy sources like solar and wind significantly reduces the carbon emission. However, the reduction of system inertia and the uncertainty of renewables makes battery storage systems almost a necessity. Depending on the use-case, different chemistries and voltages are used.

The need for grid connection of batteries, regardless of EV or stationary storage application, creates the need for a modular compact power electronics interface (PEI) with wide output voltage range. For this purpose, SiC technology-based switches are selected to make the system compact. The PEI should also be scalable, meaning the power level should be adjustable by changing the number of modules. Moreover, the PEI should be easily replaceable, and its parts should be salvageable to reduce its carbon footprint and improve its circular economy compliance.

In this thesis, a modular SiC-based PEI is designed for stationary storage applications and off-board EV chargers. The two-stage PEI is comprised of T-type active front end and dual active bridge (DAB) for AC/DC and isolated DC/DC stage, respectively. Each stage is optimized using genetic algorithm based on “average ranking”. The T-type printed circuit board layout is investigated from the point of view of parasitics, lifetime and thermal performance. For DAB, double-side-cooled SiC devices are used. During the system design, the concept of repair and re-use is adopted to further increase the circular economy compliance. Both stage controls are done using Dspace MicroLabBox FPGA domain. For the T-type decoupled current control is employed. For the DAB different modulation methods like single, extended, triple phase shift is investigated. For the high-level control methodology, a power sharing algorithm is developed for a hybrid battery energy storage system (HBESS) using machine learning approach. Compared to the standard rule-based energy management systems, it is adaptive and also includes battery lifetime in the power sharing. The developed methodology also considers different battery chemistries. Finally, the complete PEI is manufactured and verified in the laboratory where the modules are connected in series/parallel to verify the operation for 400/800 V batteries. Moreover, the system is tested for both G2V and V2G under different mission profiles to show that the same PEI can be used for HBESS.