Integrated DC fast charger in an electric vehicle

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More and more electric vehicles are starting to use a higher battery voltage than what most older DC fast chargers along the roads are capable of charging. This has led some car manufacturers to include a bulky converter just to be able to charge at the older stations. Instead, with only minor modifications to the car, the motor and inverter (normally used to propel the car) can be used as a converter when charging, removing the need for an extra one.

Many charging stations today can maximally supply 400 V. But, since it is more efficient to use a higher voltage battery, and enables even higher charging power, some new cars use 800 V. The problem is that they cannot charge at the old stations directly and thus need an additional system to convert the voltage internally. Note that this is only a transitional solution until enough new chargers are available.

A common way to increase the voltage level is to use a boost converter. This type of converter works by turning on a transistor to charge up energy in an inductor, by increasing the current flowing through it, using the lower voltage source. Then, by turning the transistor off, the energy is pushed to the higher voltage side due to the voltage drop across the inductor when the current through it decreases.

The stator in the electric motor usually consists of three sets of coils, phases, and the inverter controls the current in each one to produce torque in the motor. The phase currents are sourced from the battery and are controlled by switching pairs of transistors in the inverter quickly to keep each current around a specified value. This means that all major components to construct a boost converter are present in the vehicle already. The only modification needed is to be able to access the neutral point of the motor, the point where all phases meet, usually located inside the motor.

In this thesis a prototype was developed in collaboration with BorgWarner to test if it was possible to use the motor and inverter as a boost converter. To increase safety and simplify development of the project the proposed system increased the voltage from 24 V to 48 V instead of the 400 V to 800 V used in a vehicle. The current was nonetheless roughly equal to the one used by existing chargers.

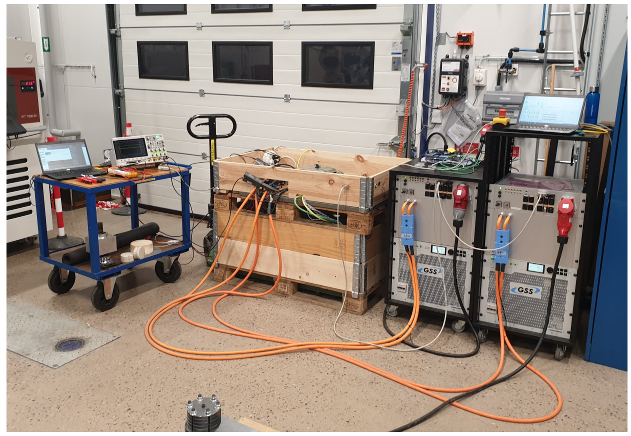

Fig. 1. The experimental setup with two high-current power supplies to the right and the boost converter, including safety systems, in the pallet stack.

It was shown that the principle can be implemented at the voltage level tested and the complete system is seen in Fig. 1. The charging current could be controlled and the efficiency was around 80 % when charging with 8 kW. Extrapolating these results to the expected operation conditions at higher voltage (80 kW with a 400 V to 800 V system) a theoretical efficiency of above 98% can be expected. Due to rough estimates however the efficiency is likely slightly too high but a much higher efficiency than that of the low voltage system is indicated.

The main problem that needs to be addressed in the future is that the phase inductance, when running equal current in all phases, is likely too small when the voltage is increased to 400 V meaning that the phase current varies too much around its reference. This causes unnecessary disturbances and puts high stress on the capacitors. This can be solved by switching the transistors in the inverter faster, interleaving the phases so that not every phase supplies its maximum current at the same time or adding an additional inductor in series with the motor to decrease the speed at which the current changes.

By using this concept in reality a significant decrease in cost and utilized space within affected cars can be achieved. This is a stepping stone as more electric vehicles transitions from 400 V to 800 V and this will hopefully reduce the price for the customers and the environmental impact of the manufacturing.