Power Electronics for E-Mobility

The number of hybrid, fuel cell and battery-based electric vehicles is increasing rapidly, and with it the requirement for a wide range of power converters. The devices are needed to charge the battery, drive the electric motor or supply auxiliary on-board units.

Electric vehicles are far more efficient than cars with internal combustion engines. However, the cost of batteries is still high and increases the relative cost of the stored energy. Therefore, highly efficient power converters are needed. Our vast experience in new semiconductors, innovative passive components and advanced cooling systems allows us to build high efficiency, highly compact on-board and stationary power converters.

Chargers for Electric Vehicles

One of the main research areas focal points in the business areas Energy Efficient Power Electronics and Zero-Emission Mobility is the grid-to-vehicle interface. A charger that connects the car battery to the grid is here a key component. We develop battery chargers for both conductive and inductive applications.

Conductive battery chargers need cables to connect the charging station to the vehicle. Electric energy is transferred either in DC or in AC form. One advantage of DC charging is that most power converters are stationary, whereas AC charging needs on-board converters. In contrast, inductive chargers allow electric vehicles to interface wireless and usually without visible stations or electric cabinets. The major benefits include improved comfort for consumers and automatic charging.
Conductive Chargers
The business area Energy Efficient Power Electronics at Fraunhofer ISE specializes in the development of conductive chargers. Our focus is the design of power converters combining utmost conversion efficiency with the highest power density. Advanced technologies – such as transformerless and multilevel inverters as well as new power semiconductor devices – play a key role in the design of innovative battery chargers for electric cars.

Inductive Chargers
In addition to conductive chargers, we also have expertise in the development of inductive power transmission systems for charging electrical vehicles. We design all converter topologies, converter stages and HF coils as well as develop the related control algorithms. Our systems profit from efficient operation and compact design. The well-designed compensation of stray fields and high voltage systems increases overall efficiency. Passive components can be downsized, when new power semiconductors switched at high frequency are implemented. Finally, magnetic fields and electro-magnetic emissions are analyzed and optimized with simulation tools such as COMSOL Multiphysics®.

Power Electronics for Range Extenders and Fuel Cells
Following the development of battery-based electric cars, fuel cells and other range extenders – such as those with internal combustion engines – are gaining importance. Indeed, batteries are still a limiting factor for the range of electric vehicles. Connecting range extenders with batteries and other electric car components requires appropriate power electronics, such as active rectifiers and DC / DC converters. These on-board power electronics units have to meet high requirements for power density, robustness and efficiency.

Grid Integration of Electric Cars
In the future, electric cars could offer a lot of grid-connected energy storage for grid stabilization. Therefore, we emphasize bidirectional charging systems for balancing power, operating reserves, reactive power and short-circuit power.

Digital Control Design
We develop innovative control approaches that fulfill all requirements for distributed generators and loads on the medium- and low-voltage grid. Simulations of inverters and battery charges are usually done with the software MATLAB® / Simulink® and PLECS®, with the goal being an optimum system design with appropriate controllers. Digital controllers are then implemented on Digital Signal Processors (DSPs) or other types of controllers. We also assist our clients and partners with digital circuit board designs and provide them with debug interfaces to test embedded control algorithms in real time.

Hardware Development
We support our clients and partners starting with the first product ideas through to pilot series. We offer all hardware development steps, beginning with system design, component selection and dimensioning, schematics, PCB design, construction and testing. The prototypes can be assessed through high precision power meters, thermal imaging and EMC measurements.

Consulting and Studies
An important part of our work is the analysis, characterization and improvement of existing designs. Since power converters should never be the limiting component in a system, we focus on thermal behavior, long-term stability and energy efficiency.

1  Resonant DC / HF power converter to supply the inductive coil.
2  22 kVA bidirectional conductive on-board battery charger for electric cars.