POWER ELECTRONICS

Efficient DC Charging Stations for the Garage

Fast charging on a SiC basis

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Direct-current (DC) rapid-charging stations can be mainly found in public spaces, while alternating-current (AC) charging concepts are predominantly used for private households. Now, however, with the DC wallbox, there is a powerful home charging option whose efficiency is enhanced by the use of SiC semiconductors.

Efficient DC Charging Stations for the Garage

To protect the climate, it is crucial to reduce greenhouse gas emissions. Electric mobility, among other things, plays an important role in reducing those emissions. The increasing number of electric vehicles (EVs) is closely linked to the infrastructure of the charging stations: The more electric cars on the road, the more charging points are available, and the improved infrastructure is, in turn, an incentive for some people to switch to an electric car. Moreover, the growth of electric mobility is driving the development of new and more powerful batteries, reducing the cost of batteries, and making it possible to build vehicles with greater capacity and range. To develop batteries with a higher power density, a high charging capacity is essential, especially if a large number of vehicles is to be charged at the same time in one place. For this reason, new charging concepts are being developed. However, particularly in cities and conurbations, the increasing number of EVs and charging stations is a burden on the stability of the electricity grid. Concepts are therefore needed to ensure continued stability. For instance, smart and networked charging points are suitable for preventing fluctuations by helping to optimize and centrally manage charging. With bidirectional charging, the battery of the electric car can also be converted into a buffer for private homes, industrial buildings, and the power grid.

DIFFERENT CHARGING CONCEPTS

About 60% of all European EV users have their own charging stations. These charging points usually operate on the basis of alternating current, with a power output of between 3.7 kW and 11 kW (in rare cases, 22 kW). Accordingly, it takes several hours to fully charge the battery of an EV. However, to use those stations, the EV needs an integrated on-board charger (OBC). AC charging stations are also used in public car parks or shopping centers. This type of AC charging station often has an output power of up to 22 kW. Therefore, the charging time for a 100-kWh battery is about five hours, depending on the OBC charging power.

If the battery needs to be recharged quickly, rapid-charging columns are the right place to go. They have high power ratings, between 50 and 350 kW, and are mainly used in public car parks and large charging stations. Depending on the size of the battery, it takes less than one hour to charge the EV using fast-charging stations; with ultra-fast–charging stations, the time is reduced to 20 minutes. In contrast to the AC version, the DC charging station has an integrated converter that transforms the alternating current from the mains into direct current. This allows the electricity to be fed directly into the vehicle's battery. Even private households and companies can benefit from stationary charging points using direct current. A variant for your own four walls, for example, is the DC wallbox (**Figure 1**), with an output of 22 kW.

The growth of electric mobility is driving the development of new and more powerful batteries, reducing the cost of batteries, and making it possible to build vehicles with greater capacity and range.

The DC wallbox can be easily installed in your garage, where it's easily combined with a photovoltaic (PV) system. PV systems generate direct current, which can be charged directly into the vehicle's battery via DC/DC converters. In addition, an energy storage system (ESS) can be installed to allow excess energy to be used. Combined with the charging station, the electric and hybrid vehicle, as well as the PV system, the storage system forms a self-contained system that allows energy demand and power generation to be optimized. ESS applications are also ideal for recycling old batteries from EVs. Although the batteries are no longer suitable as energy storage devices for the vehicle, with a capacity of between 70% and 80%, they can be used for less demanding applications, such as the ESS. These so-called "second-life batteries" (SLBs) supply the charging station with a flexible power flow, which enables a bidirectional active power exchange with the power grid. As a result, EVs can be used for load control, which optimizes the load on the grid. If shortages occur, the energy stored in the vehicle's battery flows back and stabilizes the grid (V2G).

REQUIREMENTS FOR DC

To a certain extent, user behavior is of great importance for the development of charging concepts. Ultimately, however, it is up to the OEMs whether DC charging stations will become widely accepted in private households. The crucial factor is the OBC, which needs to be integrated into every vehicle for charging with AC charging stations. Because the space and power density of the components used in a car have technical limits, the charging power of the OBC is limited. When charging with direct current, the converter is not integrated in the electric car but directly in the charging station, so components can be saved in the construction of the EV and the production price goes down. At the same time, there is more space available that can be used to make the vehicle itself more efficient. Ultimately, savings in vehicle weight also means savings in energy, which, in turn, offers a possible extension of the range.

Higher power density is achieved by selecting appropriate topologies and the appropriate components for the power level. Because of their price/performance ratio, silicon IGBTs dominate electric mobility today. The cost of SiC MOSFETs can be compensated for at system level by savings on other components, because converters based on SiC MOSFETs can be operated at a higher switching frequency than converters with silicon IGBTs.

Furthermore, SiC has excellent material properties, such as a minimal increase in

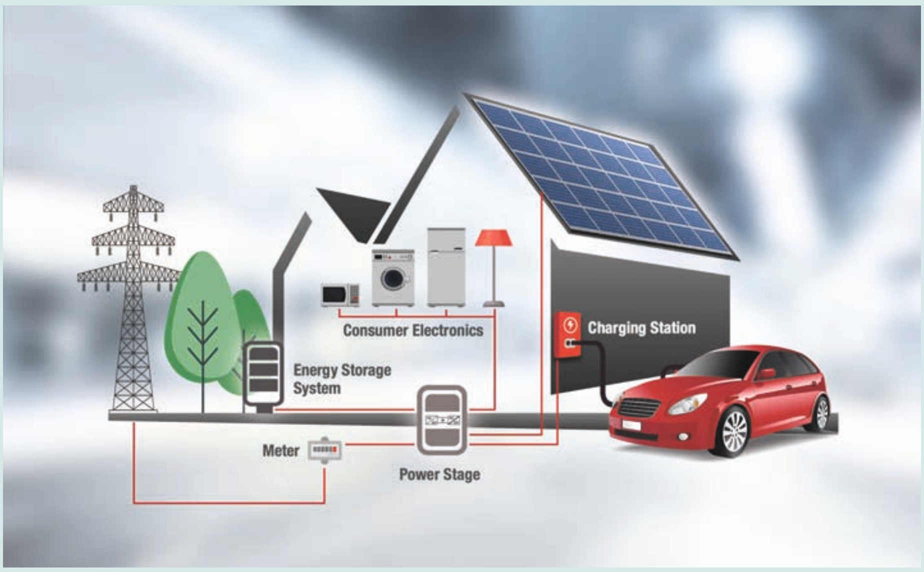

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Figure 1: *Refuel at home: The DC wallbox is a fast-charging solution for your own garage and can be connected to your home photovoltaic system.*

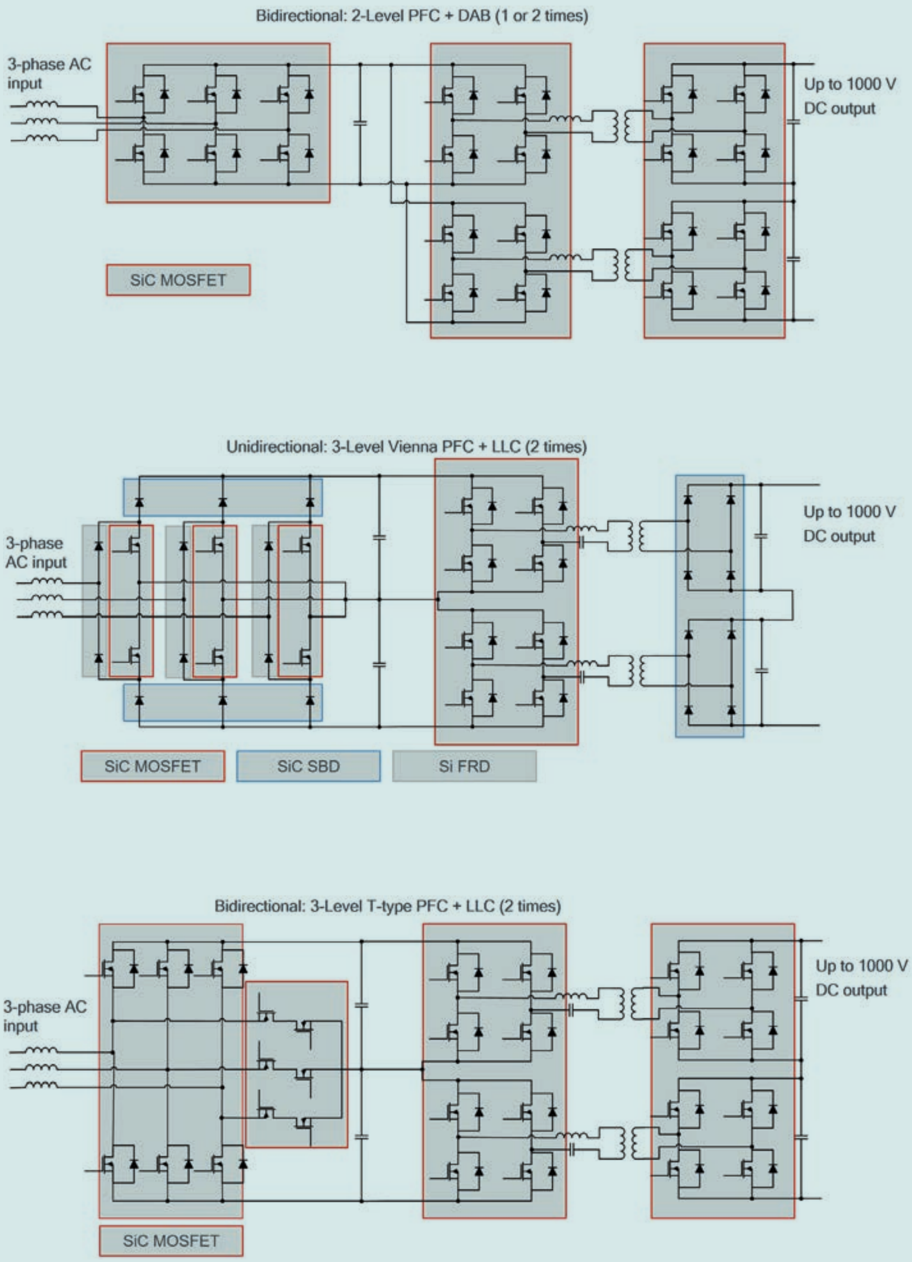

Figure 2: *Three-level topology of DC charging stations.*

forward resistance. This enables greater package miniaturization and energy savings than with silicon components. Components based on SiC can be operated at higher ambient temperatures and achieve a very high degree of efficiency. Charging stations can also be equipped with SiC MOSFETs in different topologies. Rohm has already implemented this in series production.

TOPOLOGIES OF DC CHARGING STATIONS

The charging stations do, in fact, consist of different topologies (**Figure 2**). Charging systems generally consist of two converter stages. An AC/DC stage converts the AC voltage from the mains into a DC voltage, which is then adapted to the battery voltage by the DC/DC stage. The DC/DC stage also regulates the charging current and provides the galvanic isolation required for safe operation, if this has not already been implemented on the main side.

A three-level topology requires more components than a two-level topology and has a higher gate control complexity (especially in a bidirectional configuration), which can lead to an increased system size. However, a three-level solution offers a reduction of the total switching losses and balanced EMC characteristics.

In contrast, the number of components in a two-level topology is significantly lower and the system size can be reduced. By using modern SiC technology, low switching losses and — as a result — high efficiencies can also be achieved with the two-level topology. SiC technology is therefore ideal for a DC wallbox, even if the charging voltage ranges from 200 V to 800 V.

The choice of topology depends on the respective isolation requirements of the fast-charging stations. If the natural voltage is already isolated, there is no need for complicated DC/DC circuits, which are often used for so-called "charging parks." Otherwise, DC charging stations usually use similar topologies as OBCs, although they have a wide voltage output and air cooling. These isolated lines are associated with a high financial outlay, which is hardly worthwhile for private households or public charging points. For this reason, charging stations with an isolated topology are generally used to ensure safety during the charging process.

CONCLUSION

In contrast to AC charging stations, DC charging stations have a higher power density and make shorter charging times possible. Moreover, DC charging station technology means that more space is available inside the electric car because the power of the converters is located directly in the charging points. Rapid-charging stations (DC) are particularly common in public spaces, but there are also suitable DC charging concepts for private households, such as the DC wallbox. This is easy to install in your own garage and can be connected to the home photovoltaic system.

Using power semiconductors based on silicon carbide optimizes power density, system size, and cost. However, whether private DC charging stations will really catch on is in the hands of the OEMs. They must ensure that the converters are integrated in the charging stations and not in the vehicle as on-board chargers. The space saved can be used more efficiently to make the vehicles more capable. ■

After graduating from the FH Aachen as Dipl. Mechatronic Engineer in 2008, Muzaffer Albayrak worked at Siemens AG in Erlangen as a commissioning engineer for automation systems including drive technologies. Following his personal interest in inverter technologies, he transferred to Conti Temic (Continental in Nuremberg). Albayrak spent the last couple of years as a senior business development engineer at Mitsubishi Electric B.V. In 2020, he started his career at Rohm as an application marketing manager for energy conversion.