Karlsruhe Institute of Technology

Acalable, DC-Coupled EV Charging Stations for the Stable and Sustainable Power Grid of Tomorrow

Project SKALE

The future of mobility is electric. To successfully navigate this transformation, an innovative charging infrastructure is essential. One solution to the challenge of high peak loads—caused by the simultaneous charging of many electric vehicles—lies in the intelligent integration of charging points with decentralized renewable energy sources and stationary storage systems. To meet the growing demand for charging stations, scalability is key and DC coupling will play a key role.

Demonstrator Facility

To test and further develop these technical solutions, a corresponding charging infrastructure was established at Robert Bosch GmbH. The charging system, a photovoltaic (PV) installation, and a stationary lithium-ion battery are interconnected via a DC power distribution network and linked to a central inverter, as illustrated in Figure 2. Additional vehicles can be charged on the AC side.

Figure 1: Demonstrator Facility in Schwieberdingen at Robert Bosch GmbH. Shown are the 12 DC charging points and the user display for entering parking duration. (Image: Alexander Stein)

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The demonstrator facility at Robert Bosch GmbH comprises 12 DC charging points and 5 AC charging points, each with a charging capacity of 5 kW. The system is powered by a 150 kWp PV carport. A stationary storage system with a capacity of 67 kWh allows solar energy to be buffered. All components are interconnected via a DC bus. Users input their estimated parking duration via a dedicated display at the start of the charging process.

Optimization of Operating Strategy

The central energy management system (EMS) can reduce operating costs by storing PV energy in the stationary battery and shifting charging sessions. The underlying strategy is based on forecasts of future PV generation and anticipated energy demand from incoming electric vehicles. With the additional information on vehicle parking durations – entered by users via the display – the charging load can be shifted to periods with lower electricity prices and higher PV availability. This approach also enables optimization in terms of system efficiency and battery longevity.

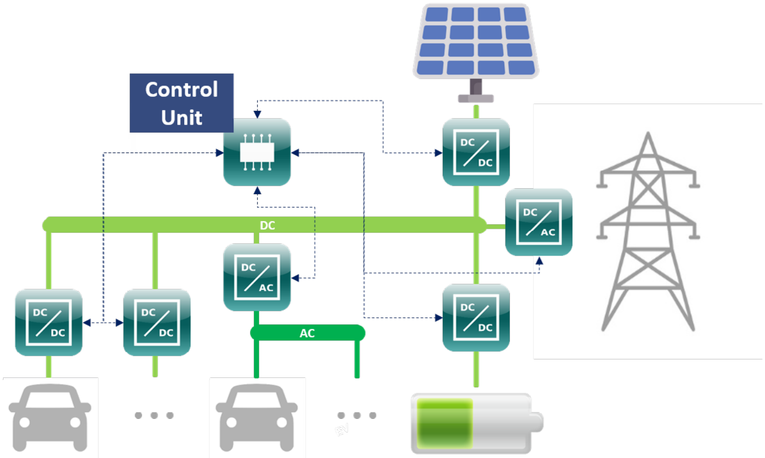

Figure 2: Scalable DC-Coupled Charging Station with Stationary Battery Storage and Photovoltaic System. [Image: Anna Starosta]

In addition to operational strategies, the project also evaluates user and vehicle behavior in relation to load shifting and overall system efficiency.

DC Coupling

When constructing new charging infrastructure, the existing grid connection is often insufficient. This issue can be addressed through a local DC network in two ways: either the DC-AC grid inverter alone meets the grid connection requirements, or the DC network is directly connected to the medium-voltage grid via a converter. Additional benefits of DC coupling include increased component efficiency and, in the long term, lower hardware costs.

A key focus of the project is the analysis of local DC network stability. This involves modeling the power electronics and analyzing component interactions. Furthermore, the project explores how local DC networks can be directly connected to the medium-voltage grid.

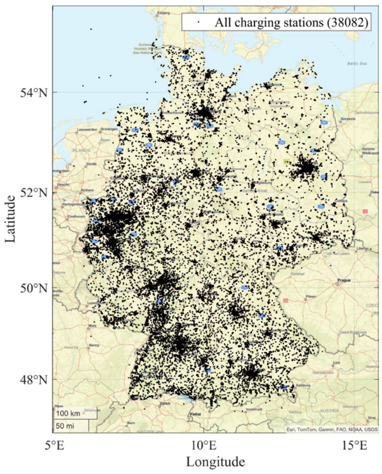

Figure 3: Nationwide Distribution of Public and Semi-Public Charging Station Locations in Germany. (Image: Anna Starosta)

A scaled laboratory prototype of a solid-state transformer is being developed to enable both technical and economic assessments in terms of efficiency and cost.

Use-Case Analyse

By the end of 2024, more than 38,000 public and semi-public charging stations were installed across Germany (see Figure 3). These stations vary in type, size, and capacity—ranging from AC to DC charging points. Differences are also evident in their surroundings, including available parking or rooftop space for PV installations such as carports. While charging stations can present the risk of increased peak loads, their locations also offer opportunities for direct load coverage through locally generated energy.

To enable transferability of project results to other systems, a simulation and optimization model was developed to determine the optimal design for economic viability, sustainability, efficiency, and system reliability. Within the framework of technical and regulatory conditions, use cases were identified that support operating public and semi-public charging stations in alignment with these objectives. These use cases include increasing self-consumption and providing grid services. Depending on the number and capacity of charging points, user behavior, and available PV surface area, a wide range of operating models becomes feasible.

Project SKALE: A Key to Tomorrow's Stable and Sustainable Power Grid

As part of Project SKALE, the Institute of Electrical Engineering (ETI) at the Karlsruhe Institute of Technology (KIT) has developed and implemented a scalable charging system on a corporate parking lot at Robert Bosch GmbH, featuring a photovoltaic installation, a stationary lithium-ion battery, and a local direct current grid. The infrastructure is designed for semi-public to private settings. By leveraging intelligent charging management and decentralized renewable energy sources, the system mitigates peak loads, improves grid stability, and enhances economic efficiency, sustainability, and overall system performance. Additionally, use cases were developed within the existing regulatory framework to support the transferability of project outcomes to future charging stations.

Project SKALE Achievements:

1. Use Case Portfolio for the design and operation of charging stations
2. Optimized Operational Strategy to increase cost efficiency and energy autonomy
3. Evaluation of DC Coupling Benefits for enhanced component efficiency

Do you have a project idea in the field of electromobility and are interested in the expertise developed in Project SKALE? We look forward to hearing from you and exploring future collaborations.

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Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

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