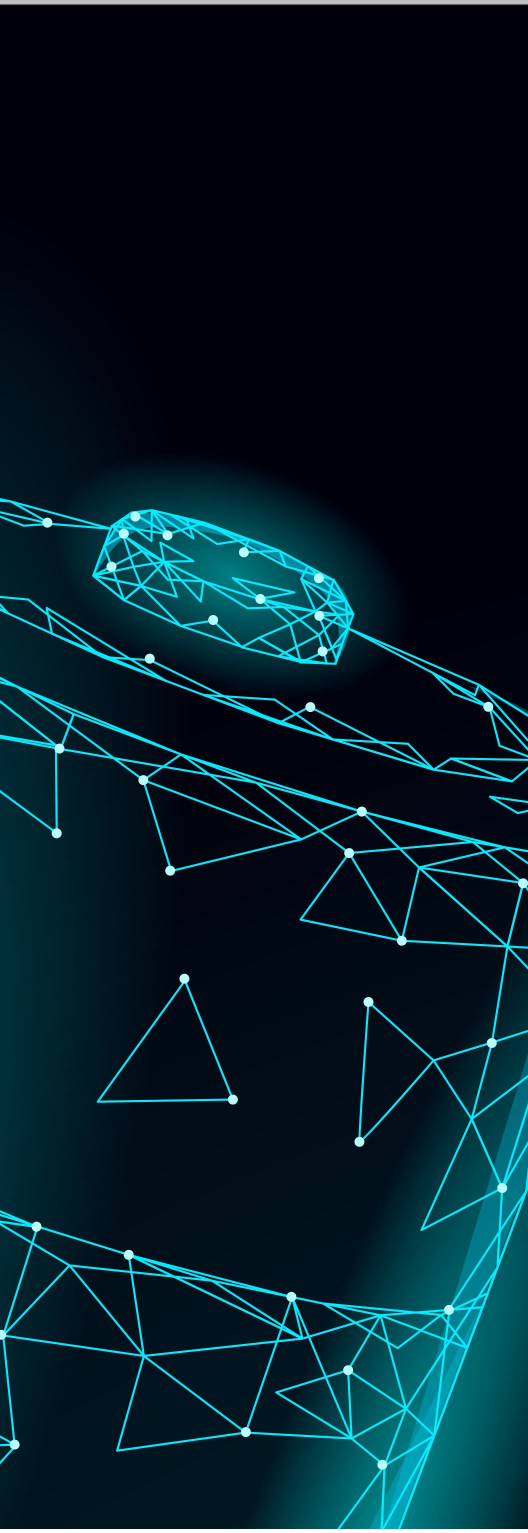
Analyzing vehicle-to-vehicle charging and its potential for future mobility

Energy Shared

Researchers from the academic and private sectors have teamed up to find a faster and more efficient way to charge an electric vehicle (EV). Their intensive study showed that a vehicle-to-vehicle (V2V) charging solution is a viable alternative that can lead to faster and wider customer adoption of EVs. A dSPACE MicroLabBox was used for testing to verify the feasibility of the V2V charging solution.



When it comes to charging an electric vehicle (EV), everyone can agree on one thing – the faster the better. However, limitations such as the availability of public charging stations, restricted grid capacities, and varying charging speeds can put the brakes on fast charging. A group of researchers from the University of Alabama, the Virginia Commonwealth University, and the University of Akron have teamed up to find a solution for this challenge. The study also involved a partnership with Andromeda Power, LLC, a California-based company that manufactures EV chargers.

The Idea: A V2V Charge Sharing Network

Power-grid-based AC and DC fast charging systems are among the most commonly used tools to charge an EV today. However, the research team is proposing a vehicle-to-vehicle (V2V) charging solution. The idea behind this: The energy is transferred between the EVs using a bidirectional DC/DC converter, which is more efficient than traditional AC/DC power conversion. Dr. Kisacikoglu, Assistant Professor in Electrical and Computer Engineering at The University of Alabama and initiator of the project, explained that most EV owners charge their vehicles overnight from their homes, but on average, they use only enough energy to commute over 25-30 miles (approximately 40-50 km). The surplus energy left in the battery could be made available to sell to other EV owners. In theory, by establishing a V2V charge sharing network, EV owners with unused electric energy on board of their vehicle could connect with users who need a charge at comparable transfer rates to charging stations. "This proposed solution can benefit not only EV owners, but also local communities, municipalities, and the supply network – especially during peak load periods." said Dr. Kisacikoglu. "A charge sharing network could provide a more convenient and flexible way to conduct EV charging at minimal infrastructure cost."

Case Study with Prototype City

To analyze and verify the viability of a V2V charge sharing network and show how such a system could impact the operation of the power grid, the research team developed a virtual environment. They used a Java-based simulation tool to generate a customized simulation environment using different parameters, such as EV types and counts, charging station types and locations, and user mobility patterns. The team created a case study using the Dallas metro area as its prototype city. The number and types of EVs that are present in Dallas were simulated, as well as the number and locations of level 2 (L2) charging stations. Next, the battery charge levels of users and their commuting patterns were factored in to analyze usage patterns of the L2 charging stations.

Adding V2V Chargers to the Equation

During the simulation activity, the impact of growing power demands on the charging stations became more and more transparent with increasing EV counts. To better understand how energy sharing can help meet power demands, the use of V2V chargers was then added into the equation. The team found that a V2V charge sharing network can yield a larger number of EVs operating in the area and meet growing demands without having to install additional L2 charging stations. In their specific use case, they found that V2V charging effectively reduced the peak

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Figure 1: A Nissan Leaf transfers energy to a Tesla Model S through a conductive charging cable. A mobile app communicates with both vehicles and lets the drivers control the charging process.

charging load by 44%, alleviating the load on the power grid system.

Evaluating Various DC/DC Converter Solutions

Once the team determined that a charge-sharing network could, indeed, have a meaningful impact on communities, they turned to the issue of transferring energy from one EV to another. They investigated three bidirectional DC/DC converter solutions: single-phase, two-phase, and three-phase conversion. To evaluate each solution, a test bench was set up that consisted of supplier and receiver EV emulators, a V2V charger solution running on three different power stages, and a dSPACE MicroLabBox to coordinate and control the charge exchange. During the investigation, the team found that multiphase, bidirectional DC/DC converters are most suitable for V2V charging as they showed a better inductor ripple current behavior compared to the single-phase counterpart.

Testing with a Closed-Loop Controller Design

Next, the team set out to validate their analysis. The V2V charger was executed in a closed-loop test bed using a dSPACE MicroLabBox. As part of the hardware implementation, a back-to-back inverter system was interfaced with the dSPACE MicroLabBox to test the different operation modes. The MicroLabBox functioned as the electronics control module, executing all high- and low-level controllers. "The MicroLabBox provided the team with a flexible controller development environment that served well for the closed-loop controller design, which operates at a switching frequency of 20 kHz," said Dr. Kisacikoglu. The tests finally confirmed what the team had established through its investigation – multiphase, bidirectional DC/DC converters should be the first choice for V2V charging.

Developing and Testing Intelligent Charging Technologies with dSPACE Tools

Did you know dSPACE offers dedicated tools for developing and testing technologies involved in the electric vehicle charging process? The new Smart Charging Solution is highly flexible and offers versatile application options, including the simulation of electric vehicle supply equipment as well as the simulation, test, and development of onboard chargers.

Smart Charging Solution – Highlights

- Prototyping and testing charging communication
- Support of region-specific charging standards
- Advanced manipulation and fault simulation options at protocol level
- Emulation of charging stations with real power

More information on the Smart Charging Solution:
www.dspace.com/go/dMag_20202_DS5366

Learn more about testing onboard chargers of electric vehicles using dSPACE tools:
www.dspace.com/go/dMag_20202_OBC

The Smart Charging Solution from dSPACE combines hardware and software components.

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Dr. Mithat Can Kisacikoglu, Assistant Professor in Electrical and Computer Engineering, The University of Alabama (Tuscaloosa, AL)

Summary and Outlook

Through their intensive study, the research team was able to prove that V2V charging could be a valuable addition in the context of future mobility concepts. Moving forward, the team plans to expand the scope of its research. They will investigate a high power density V2V charger design to improve the design footprint. The team will also seek to learn more about how it would impact more EV grid integration and its potential to integrate more renewable energy. ▪

With the kind support of The University of Alabama

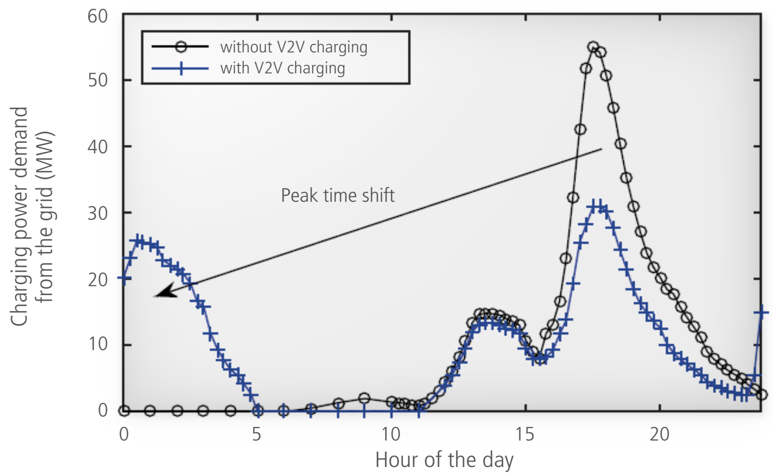

Figure 2: Distribution of charging power demands from the grid with and without V2V charging.

For more information about the study, refer to the following publication:
E. Y. Ucer, R. Buckreus, M. C. Kisacikoglu, E. Bulut, M. Guven, Y. Sozer, and L. Giubbolini, "A flexible V2V charger as a new layer of vehicle-grid integration framework," presented at the IEEE Transport. Electrific. Conf. (ITEC), Jun. 2019

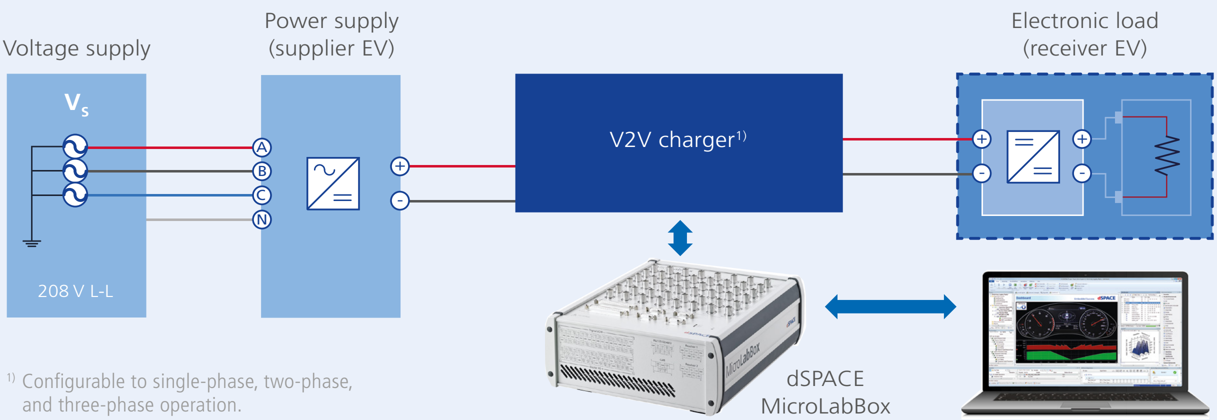

Figure 3: The research team tested three bidirectional DC/DC converter solutions for the V2V charging system: single-phase, two-phase, and three-phase conversion. The test setup included supplier and receiver EV emulators, a V2V charging solution running on three different power stages, and a dSPACE MicroLabBox.