CHARGING STATIONS IN THE SERVICE OF THE GRID

The increasing number of electric vehicles in Switzerland and the expansion of the charging infrastructure increasingly stresses the power grid. Load peaks could be avoided if the charging stations were controlled to serve the grid - i.e., accounting for local power generation and consumption - and were supplemented with buffer power storage. A research team from western Switzerland has tested this idea at fast-charging stations equipped with batteries.

Charging station for two electric cars on the EPFL campus. Photo: MESH4U

A technical report about the results of a pilot and demonstration project in the field of grids, which was financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine Bulletin Electrosuisse (issue April 2024).

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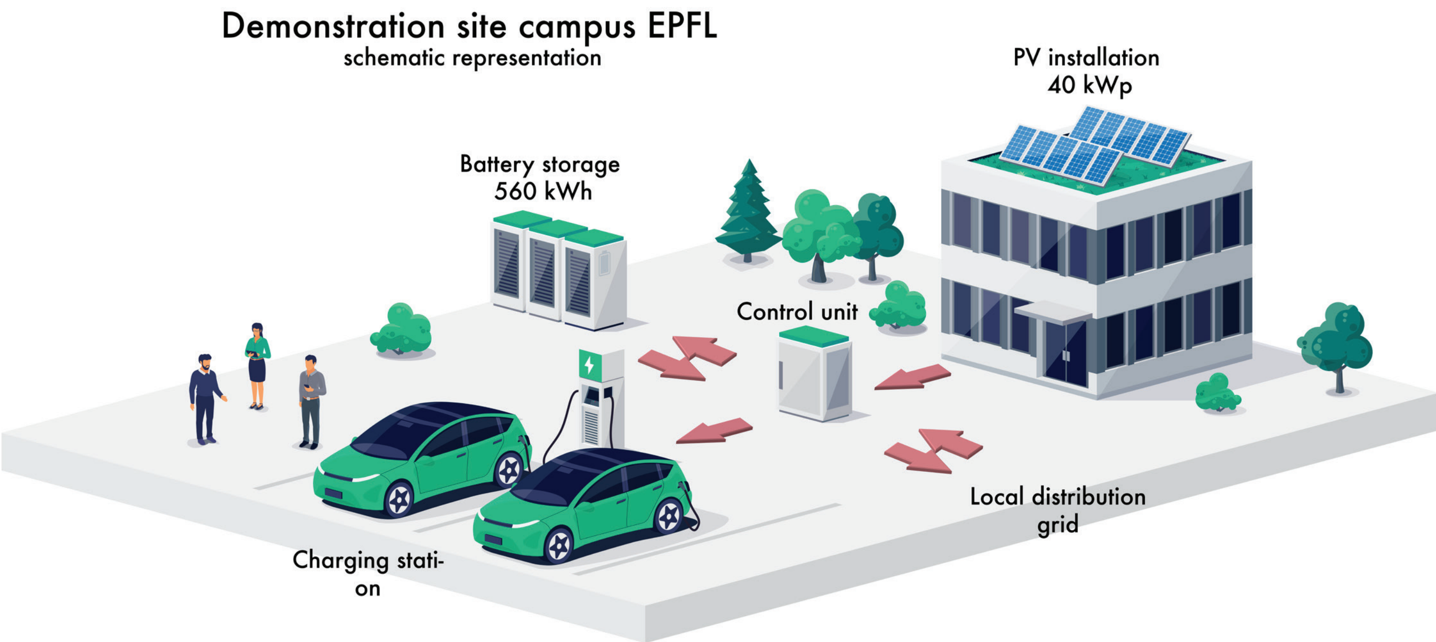


System with a fast-charging station, battery storage and PV system on the EPFL site. Illustration: B. Vogel/mit Shutterstock

Transport accounts for around 30% of the country›s greenhouse gas emissions. In order to reduce these emissions and counteract climate change, policy makers aim to extensively electrify public and private transport. With this goal in mind, a nationwide charging infrastructure is currently being developed. The electricity requirements for electric vehicles are to be met as much as possible with electricity from local renewable sources, including photovoltaic and wind power plants.

As long as only individual charging stations were in operation, the robust Swiss electricity grid could easily cope with the additional load required by electromobility. However, with the nationwide expansion of the charging infrastructure, the grid is reaching its limits. Particularly, if these electric vehicles are charged at charging stations with maximum power, the power grid will need reinforcement, which will affect the grid tariffs. To make matters worse, solar and wind power are only available at times when the sun is shining or the wind is blowing. This results in new burdens, particularly for regional and municipal electricity distribution grids.

P+D PROJECTS OF THE SFOE

The project presented in the main text was supported by the Pilot and Demonstration Program of the Swiss Federal Office of Energy (SFOE). With this program, the SFOE promotes the development and testing of innovative technologies, solutions and approaches that make a significant contribution to energy efficiency or the use of renewable energies. Applications for financial assistance can be submitted at any time.

↗ www.bfe.admin.ch/pilotdemonstration

Focus on distribution grids

A team from the École polytechnique fédérale de Lausanne (EPFL) has addressed this challenge in a pilot project with the acronym MESH4U. The scientists analyzed distribution grids that are equipped with controllable e-car charging stations and controllable battery storage systems and contain larger power plants for renewable energies. “Controllable” in this project means primarily the regulation of voltage and current so that the load on the distribution grid is minimized. The researchers investigated the controllability of fast-charging stations - both from a technical perspective and from the point of view of user acceptance. They also asked to what extent the use of a battery increases flexibility and thus enables “grid-friendly” operation of charging stations.

The study was conducted by a team led by Prof. Dr. Mario Paolone (Distributed Electrical Systems Laboratory at EPFL). The researchers worked with several partners on the project:

The software company GridSteer (an EPFL spin-off), the power utility Romande Energie in western Switzerland and the company Gotthard FASTcharge (a provider of fast-charging stations).

Charging stations in Lausanne and Aigle

As part of MESH4U, the project team set up a publicly accessible fast charging station (total charging capacity of 150 kW) on the EPFL campus where two electric cars can be charged simultaneously within 15 minutes with energy sufficient to travel 100 km (depending on the charging connector and the car). The test set-up included a large battery (560 kWh capacity) housed in a container and a medium-sized PV system (40 kWp output). All power flows in the grid were recorded using a measurement infrastructure consisting of Phasor Measurement Units (PMU). The P+D project included a second test arrangement consisting of a charging station, a battery and a centralized PV plant in Aigle (VD). This second system offers charging options for 8 vehicles simultaneously (1.2 MW charging power); the battery (2.5 MWh capacity) and the PV system (1.6 MWp output) are significantly larger than those on the EPFL campus. While the battery and the PV installation are already in place, the charging stations could not be built in time. Therefore, real charging profiles from other similar locations were integrated in the study in the form of a simulation.

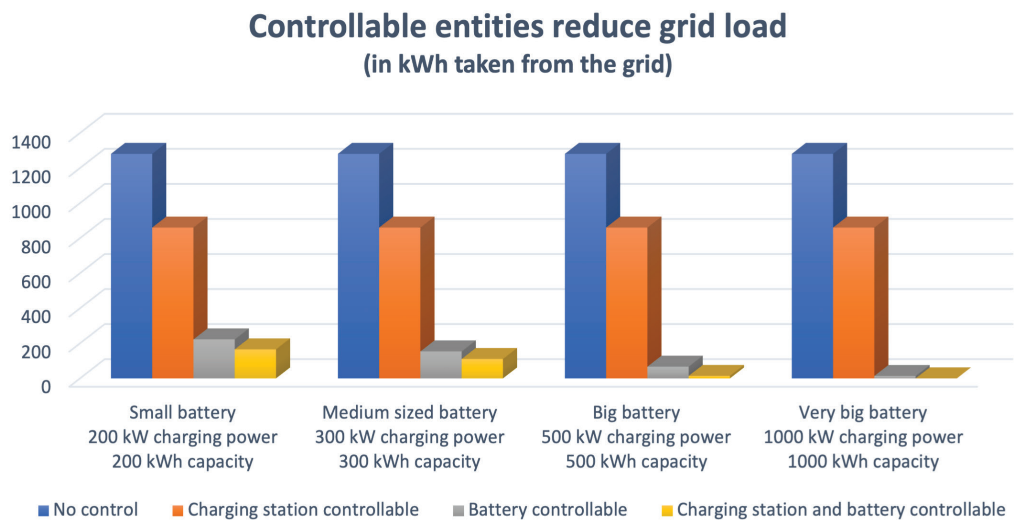
The installation in Lausanne had the advantage that people who charged their electric vehicle there could be interviewed. Based on the responses, the researchers were able to assess, among other things, how flexibly, in terms of extending the

This battery storage system with a capacity of 560 kWh helped to operate the EPFL charging stations in a grid-friendly manner. Photo: MESH4U

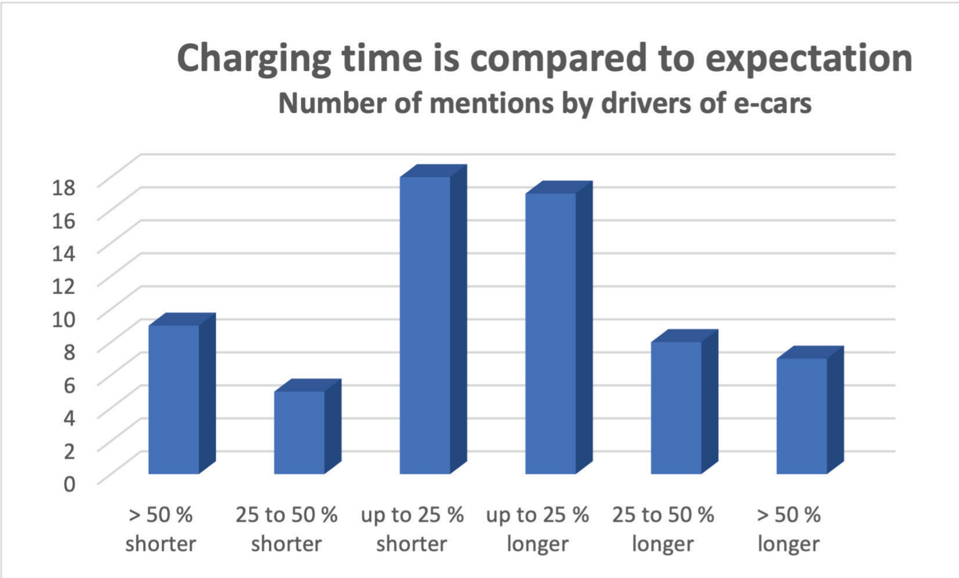
charging duration, the charging stations can be operated without restricting the comfort of drivers. To illustrate this with an example: If a driver charges their electric car during their one-hour lunch break, it should generally not matter whether the 30-minute charging process is at the beginning or end of the one-hour lunch break or whether the car is charged for an hour with reduced power, for example.

Algorithm looks to the future

In order to be able to operate charging stations in a grid-friendly manner, it must be possible to control the charging power in real time and the charging stations should be supplemented with battery storage units that can buffer electricity for seconds, minutes or hours. The MESH4U team developed



Charging stations for electric cars place a load on the grid. If the charging station or the battery, or even both, are controllable, the unplanned consumption of electricity from the higher grid is greatly reduced. If a very large battery is used, it drops to practically zero. In this case, a financial analysis is needed to compare the cost of the battery with the cost of grid reinforcement or the cost of providing incentives to users to be more flexible, as well as a combination of all of these factors. Illustration: B. Vogel using MESH4U data



In a survey, 100 drivers provided information on how long they expected it would take to charge their electric vehicle, and this prediction was then compared with the actual charging time. This showed that drivers spent an average of 10% more time charging than predicted. The EPFL researchers concluded that drivers would accept a charging process that takes a little longer due to the grid-friendly operation of the charging stations. Graphic: MESH4U

algorithms for the real-time control of the charging stations and batteries in such a way that the system requires as little additional power as possible from the distribution grid. These algorithms were used at the demo sites of the EPFL campus and in Aigle. They are based on advanced forecasting tools, which were developed by the MESH4U team, for both local PV power generation as well as the electricity consumption at the charging station for the following day.

The results of the MESH4U study show: If charging stations are combined with battery storage systems to create a controllable system, the technical prerequisites are united to optimally operate and control the distribution grid and to achieve measurable benefits. «With a real-time controllable charging system and a battery storage solution, as developed in the MESH4U project, the total daily unplanned load (i.e. the amount of load that cannot be covered by battery and flexibility and most probably needs to be imported from the grid during a day) could be reduced by a factor of ten compared to an uncontrolled system,» write the authors in the final project report. A survey of users of the charging station on the EPFL campus showed that they do allow a certain degree of flexibility in terms of when they charge their cars: A clear majority of those surveyed are prepared to allow a few minutes longer for the charging process - a third of respondents would do so without financial compensation and a further third for compensation. While the available flexibility from the controllable charging stations is limited, it can still reduce the investment in battery storage required to avoid grid reinforcement.

Second-by-second control does not work

The study also points out that there might be a delay in controlling the charging of the cars and therefore, very short time flexibilities (e.g., for a few seconds) are not valuable. The reason for this is of a technical nature: During a charging process, communication takes place between the charging station and the car. The delay between the signal from the tested charging station (GoFAST) and the response of the electric car (Tesla S90D) was between one second and one minute in the field test. The scientists leave open in their study the question of whether this limitation also applies to other vehicle types.

Charging stations that supply entire fleets of electric vehicles in companies or the public sector, e.g., garbage trucks, could play a special role in grid-friendly electromobility in the future. The charging times can be scheduled (in contrast to the random charging times at public charging stations). Charging stations for fleets can therefore be operated more easily and provide more flexibility - and that also means with a significantly smaller battery - to serve the grid. Project manager Georgios Sarantakos explains: «Compared to a public charging station with the same energy demand, a fleet charging station can allow the management of the grid with a battery that is up to ten times smaller. If you integrate schedulable and controllable fleet charging stations into the grid, you can increase the predictability and flexibility of the controllable resources of the grid. This can lead to the need for less investment in storage solution, for instance, limiting the impact of electromobility on the grid tariffs.»

Incentives create flexibility

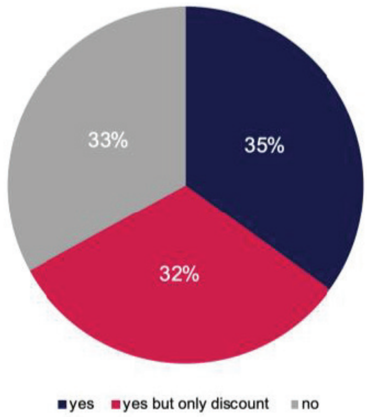
One thing is clear: incentives can increase the flexibility of car drivers. It therefore stands to reason that grid operators who want to reduce peak loads in their distribution grid should reward drivers who are prepared to extend or delay their charging process (e.g., by extending the lunch break from half an hour to a whole hour). The authors of the MESH4U study propose a pricing scheme in which charging processes are controlled via the price of the power purchased in such a way that electric cars are charged at times when the grid is under little strain.

If charging stations are equipped with batteries to achieve flexibility for charging processes, this results in additional costs. However, the authors of the MESH4U study are convinced that charging systems with a controllable charging station and battery can be operated economically in certain cases, as they write in the final report: «For economical operation, various parameters must be taken into account when dimensioning the battery storage system. These include the electricity price, the number of charging stations, the size of the transformer and the development of charged electricity volumes.» Furthermore, the MESH4U study found that the batterys return of investment could be further improved by providing additional services (notably frequency containment reserve/FCR) to the grid when the battery is not used for peak shaving.

More opportunity than risk

All in all, the MESH4U study does not see the addition of fast-charging stations to the electricity grid as a risk, but rather as an opportunity for the grid. EPFL scientist Georgios Sarantakos' assessment: «If fast-charging stations are managed appropriately, grid imbalances caused by their high electricity consumption are reduced. What›s more, controllable fast-charging stations can increase grid flexibility.

Since the flexibility can come from the car drivers and from a battery, it is a matter of an economic analysis to define whether incentives for the former or investment in the latter is required and if it is both, to which extent. The latter option requires a high initial investment, while the former provides flexibility with high uncertainty, which will decrease as more EVs enter the Swiss market. The promotion of EV fleets for companies and the public sector could be a low hanging fruit since they require relatively low initial investment while they provide high flexibility."



Answers from around 100 people to the question of whether they would be prepared to tolerate the extension of their car's charging session process by a few minutes if it meant that the charging station could be operated in a grid-friendly manner. Graphic: MESH4U

- The **final report** (in English language) on the project "Optimal integration of electric vehicles fast charging stations into medium voltage power distribution grids" (MESH4U) is available at: www.aramis.admin.ch/Texte/?ProjectID=47165

- For **information** on the topic, please contact Karin Söderström (karin.soederstroem@bfe.admin.ch), specialist for the SFOE's pilot and demonstration program, and und Michael Moser (michael.moser@bfe.admin.ch), responsible for the SFOE's Grid research program.

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Version: April 2024