CHARGING STATION BASED ON HYDROGEN

Great hopes have been pinned on hydrogen. The energy carrying gas is used, among other things, in hydrogen vehicles, where it provides the electricity for the electric drive. However, hydrogen can also be used to power charging stations that supply electric cars with electricity. In this way, charging stations independent of the power grid can be realized, which could support the expansion of electromobility in the future and provide for a mobile power supply, for example to construction sites or in the event of a disaster. This is shown by a development by the company H2 Energy and the corresponding accompanying study by the Empa research institute.

Under the name "kvyreen 80," a hydrogen-powered charging station for electric vehicles with a charging capacity of 80 kW was put into operation in St. Gallen in October 2023. Photo: H2 Energy

A technical report about the results of a research project in the field of hydrogen, which is financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine Aqua&Gas (issue May 2024).

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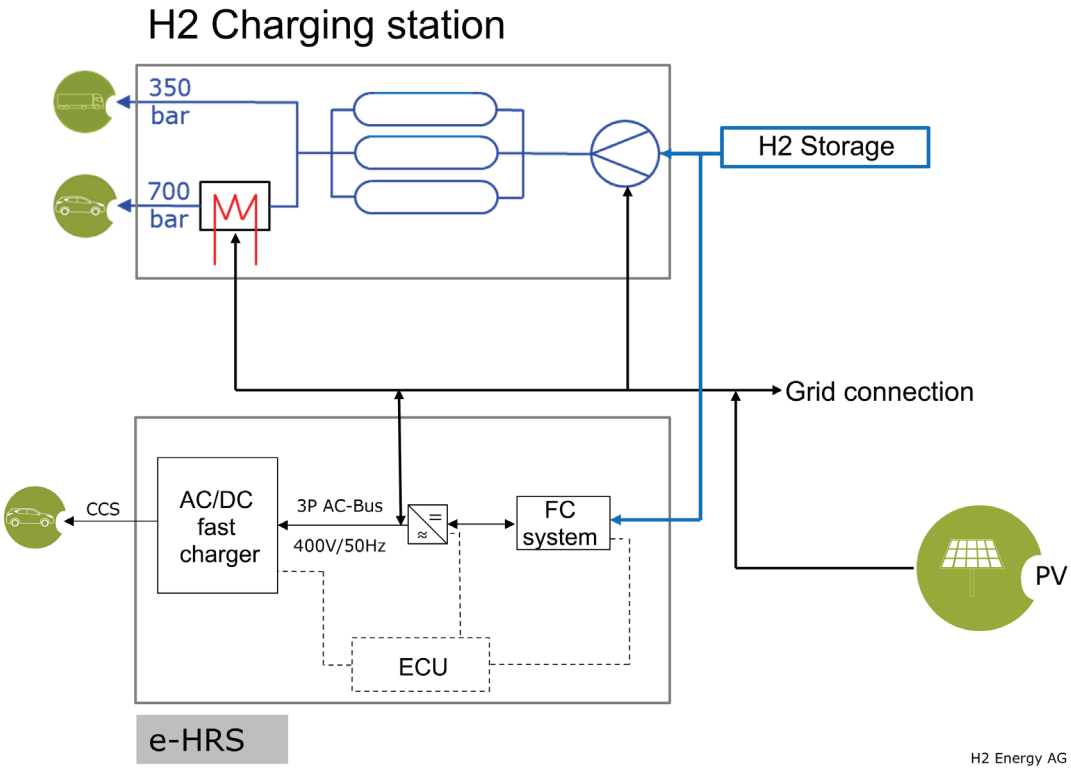
With the expansion of electromobility, an increasingly dense network of charging stations is being created throughout Switzerland. Locations include private property, public parking lots, company property or highway service areas and rest areas. As a rule, the charging stations draw their electricity from the grid. The situation is different with the charging station that was installed in St. Gallen in October 2023. Here, the electricity is generated by a fuel cell, which converts the hydrogen (H_2) stored on site into electricity. "The hydrogen-powered fast-charging station in St. Gallen avoids putting a strain on the power grid, and thanks to the hydrogen supply at the filling station, the charging power is available at all times," says Thomas Walter from the Zurich-based company H2 Energy.

The H_2-based charging station in St. Gallen has a charging capacity of up to 80 kW. This means that an average electric car can tank up with electricity for a range of 100 km in a quarter of an hour. "From 2024, we want to build and bring to market larger charging stations with an output of 150 to 500 kW, which can then also be used to charge battery-powered electric trucks. For trucks in commercial operation, high and reliable charging capacities are an absolute must, and hydrogen-powered fast chargers will significantly support grid-connected ones," says Walter. With a 500 kW charging station, an electric truck could obtain the electricity needed for 100 km in around 20 minutes.

Hydrogen-based charging station

H2 Energy was founded in 2014 and today has 80 employees. The company builds hydrogen production plants, refueling stations and applications. The company is owned by eight investors, and the Dutch commodity trading company Trafigura holds a 15% stake. In March 2022, H2 Energy had already put its first hydrogen-powered charging station into operation in St. Gallen, with a charging capacity of 60 kW at the time. St. Gallen was chosen as the location because the company Osterwalder St. Gallen AG operates a hydrogen filling station there and thus the hydrogen supply of the filling station can also be used for the fuel cell.

The 60 kW charging station was a pilot plant, and it was the focus of a two-year research project called Electric Hydrogen Refueling Station, or e-HRS, which was supported by the SFOE. With this project, H2 Energy investigated the possibility of using hydrogen as an energy source for the operation of e-charging stations. Whenever an electric vehicle needed to charge its battery, the charging station was put into opera-



H2 Energy AG

Setup of the hydrogen-powered charging station pilot unit, which was tested in St. Gallen in 2022: A fuel cell system (FC system) generates an output of up to 60 kW from hydrogen at a DC voltage of approx. 650 – 700 volts (direct current / DC). Phase-synchronized three-phase current (400 V, 50 Hz, 3 phases) is generated via an inverter and delivered to the charging station via an isolating transformer. On one side, a grid connection serves as a buffer to compensate rapid load changes of the fast charger. On the other side, it is required to start the FC system. With an electronic control unit (ECU) and specially developed software, the individual components were controlled and monitored. The charging station is supplied from the same H_2 storage system as the neighboring H_2 filling station. Illustration: H2 Energy

This hydrogen-powered pilot charging station was used 30 times to charge an electric vehicle in St. Gallen during the project period from March to August 2022. The vehicles took an average of 27 kWh of energy, with an average charging time of 34 minutes. For this purpose, green hydrogen was used, which had previously been produced using renewable electricity from hydropower by means of electrolysis. Photo: H2 Energy

tion and the required amount of electricity was provided by means of a fuel cell.

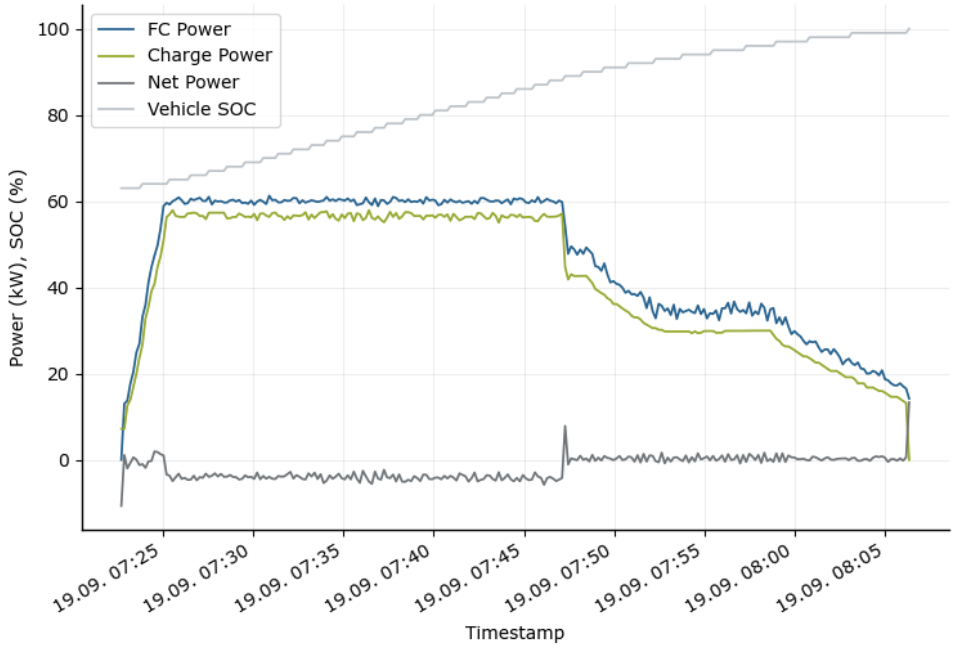
Start-up phase with power from the grid

The research project arrived at a positive conclusion: "It could be shown that this type of charging works reliably and that the system makes it possible and sensible to charge electric vehicles in a grid-friendly manner using hydrogen as an energy source," states the final report. The research project provided important insights for future hydrogen-based charging stations. Because of the way it functions, the fuel cell needs some time to start up: It takes about 20 seconds for the first current to flow, and maximum charging power is reached after two minutes.

Although the fuel cell produces electricity itself, it needs an external power supply at the beginning and during the charging process. The external power supports the starting process (with a short-term power peak of up to 10 kW) and ensures that the fuel cell continuously produces at full power during the charging process. For this purpose, the St. Gallen pilot plant built in 2022 has a connection to the power grid.

Mobile charging stations

The latest charging station, which went into operation in St. Gallen in October 2023, is independent of the power grid. The power supply during the start-up and charging phases is provided by a battery (24 kWh capacity). As a result, the charging station can operate continuously with direct current, which improves efficiency. Off-grid operation creates great advantages, says H2 Energy employee David Sauter: "Thanks to the use of hydrogen, our charging station is mobile. It can provide fast-charging capacity as needed. For example, additional charging stations can be set up in winter sports resorts and in summer at Alpine crossings or at festivals." Another



Charging process with the hydrogen-powered pilot charging station: The charging power of the fuel cell increases to a maximum of 60 kW within about 2 minutes and then lasts for a good 20 minutes. The charging capacity is slightly lower than the electricity production of the fuel cell, partly because of conversion losses due to inverters. In the second part of the charging process, full charging power is no longer required, which is why the fuel cell gradually reduces its electricity production. The graph also shows that the charging station needs external electricity (grey curve,) which in the present case comes from the power grid: At the beginning, this grid consumption is about 10 kW for a short time and then during the course of further charging, it drops first to about 5 kW and later to below 1 kW. The external power supply is required in order to be able to optimally control the power production of the fuel cell. Graphic: H2 Energy

PRIMARY RESULTS OF EMPA'S ACCOMPANYING STUDY

In a scientific study accompanying the e-HRS project, the Swiss Federal Laboratories for Materials Science and Technology, or Empa, in Dübendorf compared charging stations powered by green hydrogen with conventional charging stations. The following are the study's key findings:

• As expected, hydrogen-powered charging stations have a lower efficiency than grid-connected charging stations. If, for example, batteries in electric vehicles are charged with electricity from a hydroelectric power plant, 93% of the renewable electricity can be accessed at the grid-connected charging station (the remaining 7% is lost as transport losses in the power grid.) With the hydrogen-powered charging station, only 29% of the renewable electricity can be used (the remaining electricity is lost as transport and conversion losses). Christian Bach, head of the Empa study, comments: "High efficiencies in energy conversion are generally desirable. In the future, however, solar power in particular will play an increasingly important role, and it will be available more and more often in times when there is no demand. During such times, it makes more sense to use renewable electricity at a lower efficiency than not at all. Intermediate storage in hydrogen is one way to do this."

• Electricity from a charging station powered by green hydrogen is not completely "CO_2-free," but has a low greenhouse gas impact (17 g CO_{2eq}/kWh_{el}). This is a comparatively low value and only slightly more than if the same renewable electricity were to be obtained via a conventional charging station (4 - 5 g CO_{2eq}/kWh_{el}). However, these low values only apply to the ideal case when sufficient electricity from hydropower is available (as could be the case in the future with strongly expanded Swiss photovoltaic production in the summer months.) The CO_2 impact is higher if the calculation is based on the real Swiss electricity mix (based on 2018). In this case, the impact of the kilowatt hour of electricity at the hydrogen-powered charging station is 148 to 354 g CO_{2eq}/kWh_{el} and the electricity from the conventional charging station is 84 g CO_{2eq}/kWh_{el}. Christian Bach comments: "These considerations show that although grid-connected charging stations are advantageous in terms of the climate, hydrogen-powered charging stations can still make a contribution to climate-friendly mobility if surplus renewable electricity is available for hydrogen production. We also learn from the study that if electric vehicles are charged at hydrogen-powered charging stations with Swiss electricity, CO_2 emissions are still only half as high as with a conventional petrol engine, even in the worst case."

• Assuming investment costs of CHF 200,000, a hydrogen price of CHF 20/kg, a system service life of 10 years and a system usage of 73,000 kWh/year (equivalent to eight charging events per day), the hydrogen-powered charging station will result in an electricity price of CHF 2.20/kWh. For the conventional charging station, the price would be 70 to 80 cents per kilowatt hour. Christian Bach comments: "The figures illustrate that hydrogen-powered charging stations are not yet economical at the moment due to the current high hydrogen price and the still expensive hydrogen technologies."

In their study, Empa's team of authors emphasize that these figures represent a snapshot. If, in the future, low-cost green hydrogen were to reach Switzerland, e.g. via a pipeline, this could create the conditions for hydrogen to demonstrate its advantages as a storable energy source.

advantage is that hydrogen can be stored and transported in large quantities in tanks or gas networks.

In its Energy Perspectives 2050+, the federal government assumes that hydrogen will play a role in the future energy supply. The Federal Council intends to specify exactly which technologies it will support in a hydrogen strategy that it plans to make public in 2024. However, it is already clear that the federal government is relying on "green" hydrogen, i.e. hydrogen that is produced (by electrolysis) from renewable

electricity and not – as is still common today – from natural gas. This green hydrogen must be produced in Switzerland or imported into Switzerland via a pipeline that has yet to be built.

- The **final report** on the project "Hydrogen-powered fast charging station for battery electric vehicles" (e-HRS) and Empa's **accompanying study** "kvyreen – hydrogen-powered fast charging station for electric vehicles" are available at: www.aramis.admin.ch/Texte/?ProjectID=47408

- **Information** on the project can be obtained from Stefan Oberholzer (stefan.oberholzer@bfe.admin.ch), head of the SFOE Hydrogen Research Program.

- Further **articles** on research, pilot, demonstration and flagship projects in the field of hydrogen can be found at www.bfe.admin.ch/ec-h2

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