HOW CONVERTERS STABILIZE THE POWER GRID

Photovoltaics are being drastically expanded in Switzerland to ensure a renewable energy supply. Unlike conventional power plants, solar power systems do not need generators to produce electricity. This means that the rotating masses that stabilize the electricity grid in traditional power generating plants are missing. A study from researchers at ETH Zurich shows how the problem can be circumvented: with the "grid-supporting" operation of converters, such as those installed in solar plants, but also in wind power plants and battery storage systems.

Grid-supporting converters in battery storage systems or in solar plants and wind power stations can help to ensure that the power grid does not become unbalanced in the event of future disruptions. The photo shows 380 kV of outdoor electrical switchgear in Laufenburg. Photo: Swissgrid

A technical report about the results of a research project in the field of grids, which is financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine ET Elektrotechnik (issue June 2022).

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Disruptions to our power supply are rare. For example, when a power plant unexpectedly fails, the frequency of the alternating current supply drops below 50 Hertz (Hz) until other power plants can compensate for the failure. An increase in frequency, on the other hand, can occur when a large power consumer is cut off from the grid. In such a case, temporary power overproduction results and the current frequency climbs above 50 Hz until power plants have curbed their production.

The power supply is designed in such a way that disturbances are usually corrected within seconds: Thanks to the automatic adjustment of power plant output (called control reserve), the balance between production and consumption is quickly restored, and the grid electricity frequency returns to the setpoint of 50 Hz. Sufficiently large power plant capacities contribute to grid stability, as does a closely meshed grid. The design of the power plants also plays an important role: Hydroelectric, nuclear or gas-fired power plants use large generators to produce electricity. The rotating metal elements have inertia that stabilizes the power grid by counteracting excessively quick frequency changes. In addition, the windings of the generators contribute to the damping of frequency oscillations.

Swiss nuclear power plants (3 GW capacity) contribute to grid stability via installed generators. When the plants are shut down, this benefit can be achieved by grid-supporting converters installed in batteries and PV systems, for example.
Photo: B. Vogel

Reduction of inertia endangers grid stability

With the planned nuclear phase-out and the expansion of solar energy, the share of generator-based power plants will decline in the future. Grid experts view this development with concern because solar plants do not have generators with grid-stabilizing inertia. They lack the ability to passively dampen oscillations. Moreover, they usually do not participate in reserve mechanisms, organized by Swissgrid and the other European transmission system operators, to provide power in the event of a disruption. “If we expand solar power and at the same time take conventional power plants off the grid, the converters must be able to contribute so that the grid continues to find its way back to equilibrium in the event of disturbances,” says Dr. Alexander Fuchs, a scientist at the Energy Networks Research Unit of the Swiss Federal Institute of Technology Zurich (ETHZ).

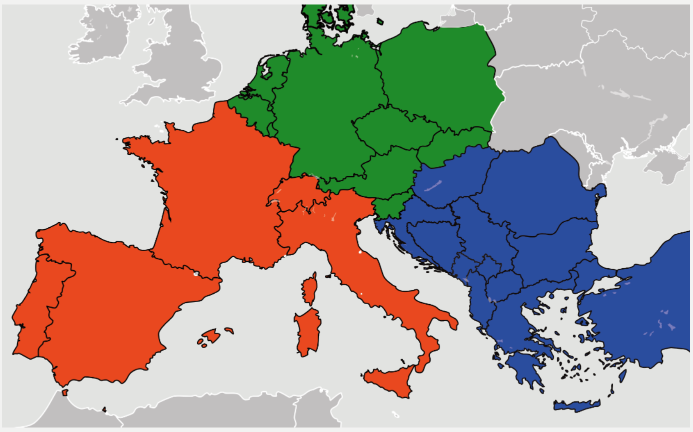
This is possible because modern converters are able to reproduce rotating masses when they are operated in a “grid-supporting” mode. This applies to converters installed in solar plants, battery storage systems and electric car charging stations, but also to the converters used in wind turbines so that they are able to feed the electricity of generators rotating at different speeds with a suitable frequency into the AC grid. If the converters are intelligently controlled via suitable software, they contribute to grid stability in the same way as the generators of traditional power plants do.

“Grid supporting” converters

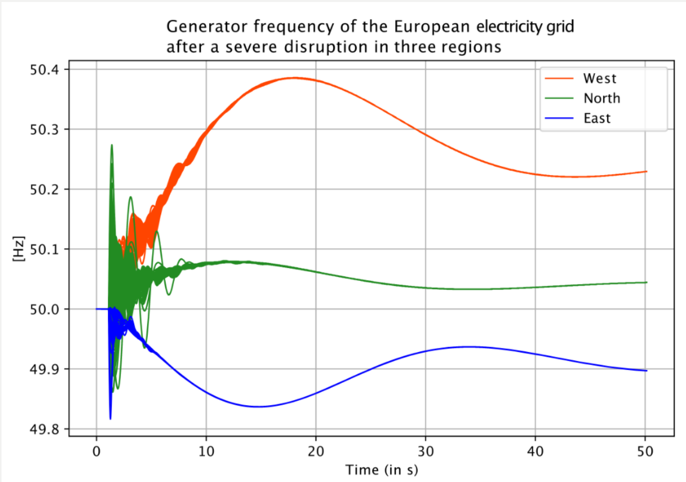
Fuchs, together with a team of researchers, has investigated how grid stability can be ensured even with a major shift in energy supply toward solar and wind power. The team includes a scientist from Hitachi Energy Research, previously part of ABB Corporate Research. In their study, the researchers used computer simulations that describe the dynamic behavior of power grids. The project was supported financially by the SFOE.

In order to ensure grid stability, not all new converters installed in the power grid must be operated in a grid-supporting

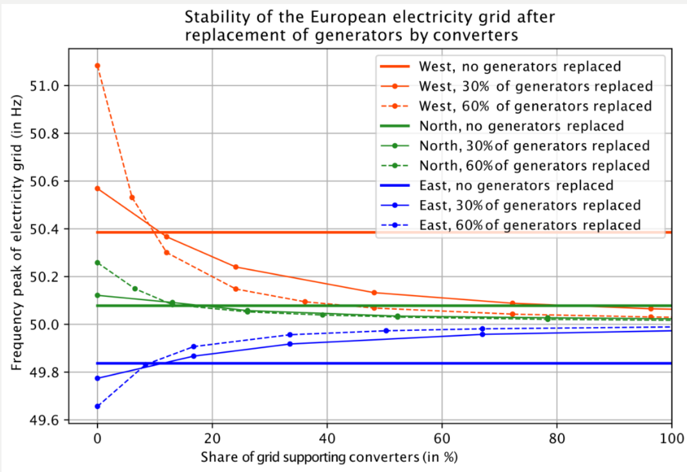
AROUND TEN PERCENT OF CONVERTERS MUST BE “GRID-SUPPORTING”



The research team from ETHZ and Hitachi Energy Research used the European transmission grid as an example to calculate the consequences of producing electricity in solar and wind power plants using converters instead of the conventional generators used in coal, gas, nuclear or hydroelectric power plants. They used a simplified model from the European Network of Transmission System Operators for Electricity (ENTSO-E). In this model, Europe's electricity supply consists of approximately 1000 generators (120 GW capacity) distributed across the continent, supplying 12,000 distribution networks and other large consumers.



The research team looked at an incident that actually occurred in 2006. At that time, the continental power grid broke down into three parts with different frequencies: Western and Northern Europe (red, green) and the countries of Eastern Europe (blue). Because of the resulting imbalance between production and consumption, there were striking deviations from the target frequency (50 Hz): In the simulation, the frequency peak in Western Europe reached almost 50.4 Hz (high power surplus), in Northern Europe almost 50.1 Hz (low power surplus), while in Eastern Europe it dropped to about 49.85 Hz (power shortage) (see graphic in the middle). Thanks to the stabilizing function of the 1000 generators, the frequency deviations were not significantly higher and did not cause a blackout.



The ETHZ researchers now wanted to know what would have happened in the scenario if 30 or even 60 % of the generators had been out of service at that time (because the power plants were replaced by solar and wind power plants in the course of the energy system transition). The graph (see graphic below) shows that in this case, in Western Europe for example, the grid frequency would have skyrocketed to around 50.6 Hz (30 % less generators) or even above 51 Hz (60 % less generators). To counteract this massive grid imbalance, the researchers equipped some of the converters from solar and wind power plants with “grid assist” control capabilities in the simulation. The more converters that were operated in a “grid-supporting” manner, the smaller the frequency spikes became. If about 10% of the newly installed converters of solar and wind power plants in Western Europe are operated in a grid-supporting manner, the frequency deviations can be limited to the same level as if 1000 generators were in operation.

In other words, 10 % of newly installed grid-supporting converters operating in a grid supporting manner are sufficient to ensure grid stability. The observation from the Western European region applies similarly to Northern and Eastern Europe, even with variation in power exchange between the separate power grids. Regardless of the scenario... => *continuation p. 4*

Grid control center of the national grid company Swissgrid in Aarau. The Swiss transmission grid is managed from here. Grid-stabilizing components from power plants and battery storage systems support the reliable operation of the power grid. Photo: Swissgrid

mode; it is sufficient if only a portion are operated in this manner. In its study, the research team from ETHZ and Hitachi Energy Research estimated what proportion of the converters would have to be operated in a grid-supporting manner so that during the period of conversion to solar, grid stability does not deteriorate. The study conclusion: If power plant output from generators is replaced by photovoltaic systems in Switzerland, around 10 % of the new PV systems would have to be operated in a grid-supporting manner so that grid stability does not suffer.

Batteries as preferred solution

Grid-supporting converters thus have great potential to contribute to grid stability. But the question of how they will accomplish this in a future energy system remains open; research is still at an early phase. For example, it is possible to operate a converter from a PV system in "grid support" capacity, but this makes little sense because a PV system can only support the grid when it is producing electricity. However, the grid support function is required around the clock. "We assume that in practical implementation, the grid support function will be mainly performed by batteries in the future. From today's point of view, this is the only practical solution. It is the only way to call up grid support around the clock," says Fuchs. "The easiest way would probably be to upgrade the batteries for grid support, which are installed by homeowners with PV systems anyway."

In order to pave the way for such solutions, the ETHZ scientists would like to investigate variations of the implementation of grid support, including integration into different distribution grid types (urban grids, rural grids, industrial grids). The researchers don't expect the cost for any new solution to be an obstacle: "If converters of the latest generation are

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about 10% of grid-supporting converters maintain the stability of the electricity grid to the same degree as if the power plants are still in operation, according to the calculations of the research team. Transferring this finding to the Swiss power supply in a thought experiment: To achieve the contribution to grid stability currently provided by the Swiss nuclear power plants (3 GW of installed power) with converters (e.g. in batteries or PV systems), 300 MW of them need to have a 'grid-supporting' technology. This is about one tenth of the PV capacity currently installed in Switzerland (end of 2020). BV.

used, in principle only a software update would be necessary to be able to operate them in a grid-supporting mode."

- Further information is available on the project website.

- The **final report** on the SFOE research project "ACSI-CON - Novel Analysis and Control Solutions for Dynamic Security Issues in the future ENTSO-E network with high Converter-Based Generation" can be found at: https://www.aramis.admin.ch/Texte/?ProjectID=41465

- For **information** on the project, please contact Dr. Michael Moser (michael.moser[at]bfe.admin.ch), Head of the SFOE Networks Research Program.

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

If 3 GW of the European power supply is disrupted, the frequency in the grid drops by 0.2 Hertz. The photo shows an overhead powerline between Gösgen and Laufenburg. Photo: Swissgrid

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