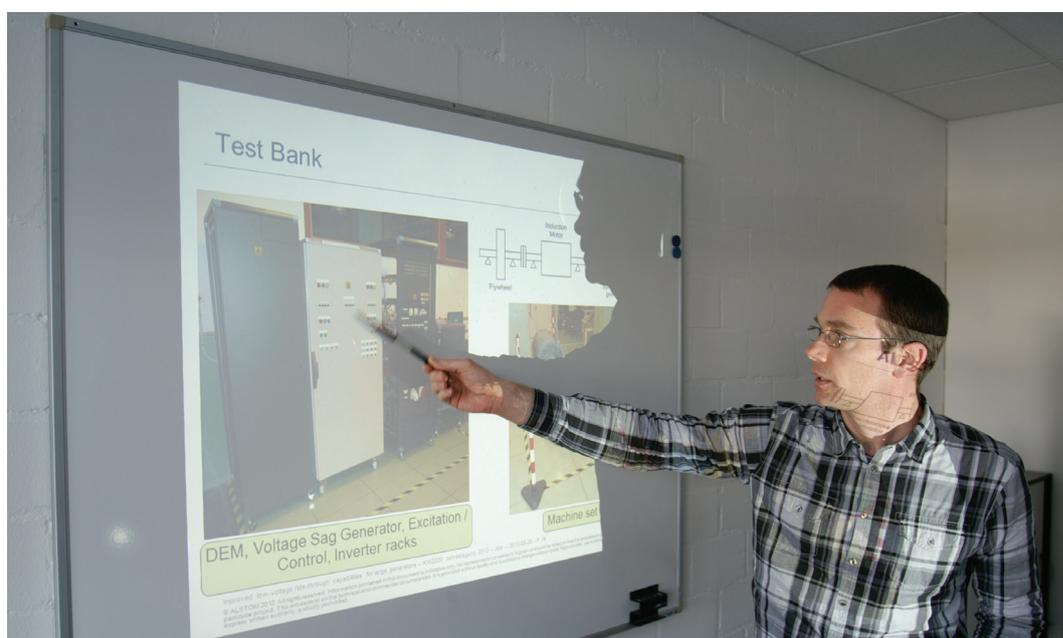


More stable power thanks turbogenerators

Turbogenerators in gas, coal and nuclear power plants convert rotational energy into electricity, which is then fed into the electricity grid. Large voltage fluctuations in the electricity grid, however, can affect the generators. The industrial group Alstom Switzerland has developed "Excitation Booster Technology" to protect the electricity network against turbogenerator outages under extreme voltage fluctuations. The technology could contribute to grid stability and thus help to ensure the security of the electricity supply in the future.



Johannes Menzel, head of the Excitation Booster research group at Alstom Switzerland, next to photographs of the Excitation Booster test unit. Photo: B. Vogel

Dr. Benedikt Vogel, commissioned by the Swiss Federal Office of Energie (SFOE)

The Swiss electricity grid is extremely stable because it is closely intermeshed and connected in many places with the power grids of neighboring countries. In the event of grid failure, these neighboring countries will help Switzerland to bypass electricity shortages. This safeguard is missing, for example,

in stand-alone grids such as in Great Britain or in Ireland, and also in networks with low meshing. Here strong voltage dips in the power supply may occur – such as from short circuits, from shutdown of an entire grid section or from the failure of a large power plant unit. In such extreme cases, the voltage in such a high voltage grid can drop from a normal 220 kV to 160 kV or less. Such a large voltage dip would most certainly affect the

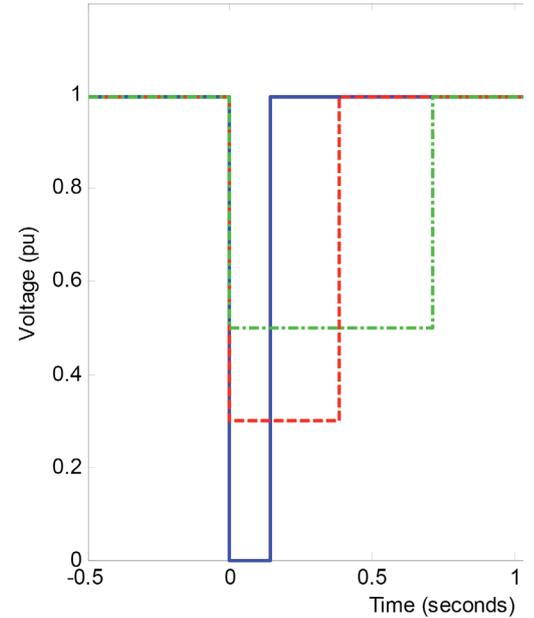
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generators at power plants connected to the electricity supply.

Generators do have the ability to compensate for minor voltage fluctuations in the grid, but only up to a certain degree. Large voltage fluctuations such as in the above example, can knock generators out of step and in the worst case, out of the grid – which may lead to a cascading deterioration of the existing electricity shortage. To avoid such scenarios as much as possible, especially under the difficult conditions of the deregulated electricity market, network operators have established so-called grid codes that set increasingly stringent technical minimum requirements that must be met by generators to survive any voltage dips.

Power plant operators call Alstom to help

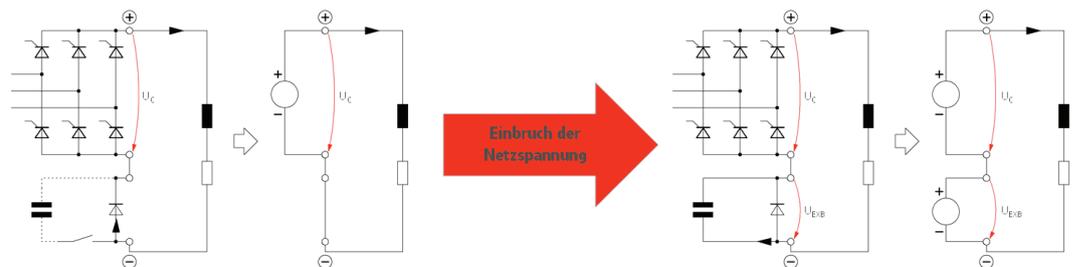
A few years ago, the operator of a European electricity grid focused his attention on the intensification of the grid codes in order to increase the stability of their (island) network. The new requirements for the generators were so rigid that a local gas power plant operator feared he would not be able to continue to operate their turbogenerators much longer. He turned to the manufacturer Alstom with the question of how the turbogenerators could be upgraded to meet the new strict requirements. This question triggered an exciting research project at Alstom Switzerland in Birr (AG) with support from the Alstom site in Mannheim (Germany). The project has been led by Johannes Menzel who directed a development team along with



The diagram illustrates three different lengths and different degrees of voltage dip incidences, as defined in the grid code for the English electricity grid. Graphics: Alstom

specialists from neighboring fields to work on the electrical design of turbo-generators.

In order to protect a generator against a voltage dip, one must find a way to bridge this fluctuation. The starting point is the static excitation equipment of the generator. The excitation device is a component to create a magnetic field with the help of a continuous current. The magnetic field is essential for the production of electricity in the generator. The excitation device helps the generator to compensate for voltage fluctuations, provided they do not exceed a certain amount. The aim of the Alstom-research pro-



The Excitation Booster consists mainly of an array of capacitors that provide the voltage U_{EXB} to compensate for a voltage drop in the power grid. In the circuit diagram, the Excitation Booster on the left is inactive, on the right it is active. Graphics: Alstom

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ject was to build a voltage source to operate the excitation device independent from the main power supply. This would be capable of compensating for a voltage drop in the electricity network for a short time (a few hundred milliseconds), so that disturbances in the grid could be “driven through.” Because the excitation device normally operates with the voltage supplied by the power grid – a strong break in the grid would render the excitation device inoperable.

High-performance storage compensated voltage dip

The new power source developed by Johannes Menzel and his research colleagues,



View of the machine unit where the calculations for models of the Excitation Booster were validated. Photo: Alstom

which is based on Alstom patented technology, is called Excitation Booster. The Excitation Booster consists of a powerful energy storage device and accompanying power electronics, which ensure coupling with the excitation system. The energy storage device consists of an array of capacitors that, in a split second, must be able to provide a capacity of up to

8 MW of power. The associated power electronics consist mainly of a high-power diode, which has the function to couple the energy storage to the main current path. “This ‘flow valve’ on the one hand ensures the simple and robust connection of the energy storage unit to the excitation system. On the other hand it also ensures that a (partial) failure of the Excitation Booster does not cause an operational disruption of the entire system,” said Johannes Menzel, “which is the primary distinction between our technology and other manufacturers that are pursuing similar research.” Through the special coupling of the diode, the interface to the excitation system is made very simple, allowing easy integration into existing systems (upgrade / retrofit).

The Alstom researchers have implemented their technical concept in a test facility. This was conceived and built by Spanish project partners, the Universidad Pontificia Comillas in Madrid. “With the test we were able to show that our system works in practice and we were able to validate our simulations for the electrical behavior of the system,” says Johannes Menzel. The test facility is a replica of a power plant with a turbogenerator of 10 kW (the turbo-generators manufactured by Alstom are 4000-200000 times more powerful). Part of the facility is also a module that can simulate several scenarios for voltage dips of real electricity networks at a level of 400 volts. The test facility’s generator is driven by an electric motor, which reproduces the function of a turbine, but is more easily adjustable than a proper turbine. The inertia behavior of the turbine drive train is simulated by a fly-wheel.

Ready for product development

“Thanks to the validation data from the test, we now have a model for the Excitation Booster that we can scale up for applications in turbogenerators with up to 400 MVA power,” Menzel summarizes the findings of the research project. Technology development of the Excitation Booster is complete, a patent exists. Nevertheless, there will initially be

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no commercial application of Alstom's new generator tool. In the case of the mentioned power plant operator, the local grid operator has provisionally agreed to accommodate him with respect to the grid code, so that for the time being there is no need, at least in this case, for the Excitation Booster.

But Menzel is convinced that the time will come for the innovation: "Grid stability specialists agree that the issue will soon be back on the carpet." He is referring to the Association of European Transmission System Operators (ENTSO-E), based in Brussels, that is working on new requirements for operators of turbogenerators. Especially since there is growing input of power from wind and solar energy plants – energy sources that are strongly dependent on weather and consequently fluctuate wildly, which will only increase the instability of electricity networks. Consequently, demand for the Excitation Booster could arise in Europe first and then worldwide. Whether the Excitation Booster is ever used in Switzerland remains to be seen. That will depend in no small part on the role gas powered energy plants will play in the country's new energy policy.

- » For further information on the project, please contact Peter Jansohn (peter.jansohn[at]psi.ch), head of the BFE-research program Power Plant 2020 / CCS.
- » Further technical papers about research, pilot demonstrations and lighthouse projects of Power Plant 2020 / CCS can be found here: www.bfe.admin.ch/CT/gas

A broad application range for turbogenerators

Whether water, wind, gas, coal or nuclear power plant, generators are required to produce electricity. Generators for thermal power plants (gas, coal, nuclear) are generally called turbogenerators. Alstom manufactures four types of turbogenerators:

1) air-cooled turbogenerators for gas fueled power plants and combination power plants (electricity producing gas powered plants that in addition to a gas turbine also employ a steam turbine to take advantage of waste heat from the gas turbine) in the power ranges of 50-165 MVA and 140 to 400 MVA.

2.) hydrogen-cooled turbogenerators for larger combined power plants in the range of 320-710 MVA.

3.) hydrogen and water-cooled, two-pole turbogenerators for large thermal power plants, especially coal fired power plants in the range of 430-1400 MVA

4) Hydrogen and water-cooled, four-pole turbogenerators for large thermal power plants, especially for nuclear power plants with 850-2235 MVA

The group mentioned under 1) to 3) are also available as a phase shifter machines (Synchronous Condenser) for reactive power control. BV