Energy
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Project

Cycles of compressed air storage

Compressed air storage power stations represent efficient alternatives for electricity storage

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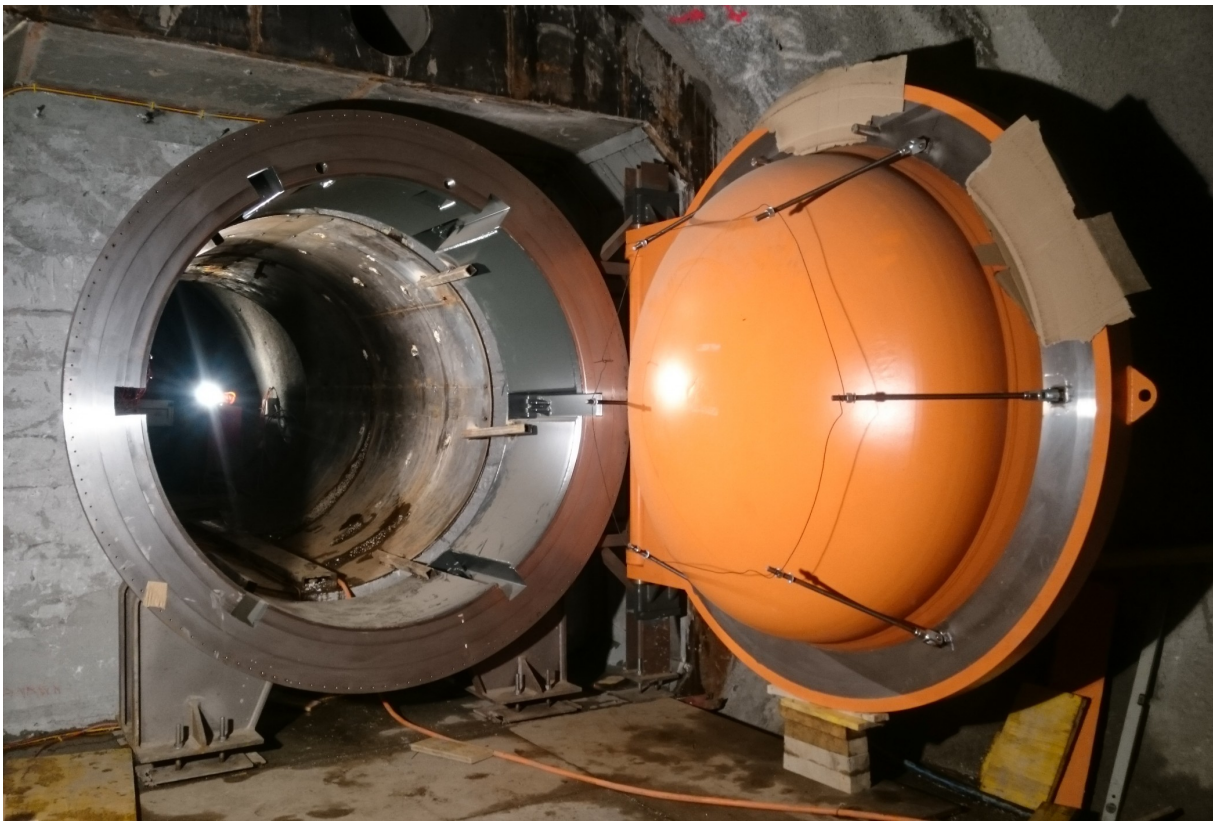
Electricity generated from renewable sources can be stored in the form of compressed air. Researchers from the University of Applied Sciences and Arts of Southern Switzerland (SUPSI) simulated a compressed air storage power station of this kind in a computer model and calculated its efficiency, costs and best-possible development. The results represent an important step in realising such plants in Switzerland.



A compressed air reservoir in the Alps: the storage of electricity generated from renewable sources is being tested here.
Source: ALACAES

At a glance

- As the supply of electricity generated from renewable sources fluctuates depending on the weather and the time of year, technologies that allow for its storage are absolutely essential.
- The capacity of the pumped-storage power plants that currently store electricity in Switzerland will not suffice.
- These pumped-storage power plants can be supplemented with compressed air reservoirs with heat recovery, as this project shows. At present, they have a theoretical efficiency level of 75 %.

In 2050, 20 % of electricity needs in Switzerland should be covered by solar energy. However, depending on the weather and time of year, solar electricity is either more or less readily available. It is therefore important that electricity can be stored efficiently using solutions with large capacities. In Switzerland, it is primarily pumped-storage power plants that are available to this end. But their storage capacity will not suffice if ever more electricity is to be produced from renewable energy sources. Furthermore, the reservoirs required for new pumped-storage power plants have a significant impact on nature and the environment.

The storage of electricity in so-called compressed air reservoirs could offer an alternative. Here, the temporarily excess electricity drives compressors that compress the air and press it into a closed cavity in the rock. This compressed air can then drive turbines and generate electricity once more when this is required at a later time.

Saving compression heat

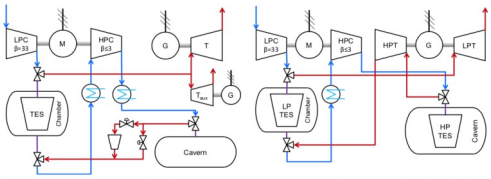
When the air is compressed during the loading of such a reservoir, so-called compression heat is generated. At the already existing compressed air reservoirs in Huntorf (Germany) and McIntosh (US), this heat goes unused. Furthermore, the air in these plants has to be warmed up once more during the unloading process as it cools upon expanding and would ice up the turbines. It would be more efficient to also store the compression heat and use it at a later time to warm up the compressed air before it drives the turbines.

A project team headed up by Maurizio Barbato from the “University of Applied Sciences and Arts of Southern Switzerland” investigated how exactly a compressed air storage power station with an additional heat storage solution of this kind could be developed and how efficient this would be. With the help of the “Technology Assessment Group” of the Paul Scherrer Institute, the researchers also calculated the costs of such a power plant.

On the basis of a computer model, the researchers simulated a compressed air storage power plants with all of its components: compressors, caverns for the compressed air, nozzles for pressure equalisation, heat storage technologies and turbines. The characteristics of these components, for example the capacity of the storage devices and the output of the turbines, were precisely defined by the researchers, who compared two different development plans.

Different development plans

A first development plan only incorporated a single heat store in a special pressure chamber. This design has a problem, as revealed by the computer simulation: during the unloading of the compressed air reservoir, the pressure difference between the cavern and the heat store has to be balanced out via a nozzle. This takes several hours, making the plant inefficient. For their further analyses, the scientists therefore opted for a second development plan. This included two heat stores, with one located inside the cavern. The analysis showed that no waiting time is necessary for the pressure equalisation process with this configuration and that both the temperature and pressure levels in the heat store fluctuate less significantly during the loading and unloading cycles. This is beneficial for the operation of the plant.



Welcher Aufbauplan eines Druckluftspeicherkraftwerks effizienter ist, haben Forschende im Computermodel untersucht: Mit einem (links) oder zwei (rechts) Wärmespeichern. Wissenschaftlicher Abschlussbericht

On the basis of this second development plan, Barbato and his team then analysed how the plant would behave during the course of long-term operations. To this end, they simulated 200 loading and unloading cycles over a period of 85 days. The researchers also simulated fluctuations in the electricity grid as they could realistically occur during the course of a week. Furthermore, the simulated compressed air storage power station had to return the stored electricity with an output of 100 megawatts. The simulation provided numerical values for the fluctuations in temperature and pressure in the heat stores and caverns. These figures are useful as they can be used to ensure the better planning and operation of a compressed air storage power station in future.

High efficiency

The researchers were also able to calculate the overall efficiency of a pilot system comprising a compressed air reservoir with heat recovery that was set up as part of the joint project in a Ticino mountain mine. To do so, they took the energy that the turbines released and the energy used by the compressors: according to their calculations, the modelled storage power plant had an efficiency level of 75 %.

Thanks to their detailed model, the researchers were able to compute the costs for a compressed air storage power station with a lifetime of 60 years in Switzerland. Here, they factored in the price of the energy required to load the compressed air reservoir together with the calculated efficiency of the plant. The costs for development, operations and maintenance were also taken into account. The total system costs amounted to CHF 139 million; the costs for storage totalled CHF 200 to CHF 300 per kilowatt hour. However, the researchers point out that against the backdrop of the current market situation the electricity stores do not pay off. The researchers therefore recommend subsidising the development of the compressed air storage technology. This would mean the technology is available when renewable energies someday increase in significance and electricity storage solutions thus also become more important and economically viable.

Produkte aus diesem Projekt

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