Energy
National Research Programmes 70 and 71

Project

Electricity storage via adiabatic air compression

Electricity can be stored in mountain tunnels – using a compressed air battery

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To store electricity from renewable energy sources, researchers from ETH Zurich, the Swiss Federal Institute of Technology Lausanne (EPFL), the University of Applied Sciences and Arts of Southern Switzerland (SUPSI), the Paul Scherrer Institute and the company ALACAES have tested a new type of compressed air reservoir in the Alps. The system is environmentally friendly. But it is still unclear whether such storage systems will turn out to be profitable.

The inside of a compressed air reservoir – here, compressed air is stored in the mountain. *Source:* ALACAES

At a glance

- Compressed air reservoirs use electricity from renewable sources to compress air – this stores the energy.
- In an old mountain tunnel in the Ticino Alps, a group of researchers have successfully tested a pilot system.
- As this system is particularly efficient and environmentally friendly thanks to an additional heat accumulator, it represents a possible storage solution for the future.

There is too much on summer days and too little at night: electricity from solar energy. Wind turbines are also not very reliable: sometimes the wind blows, sometimes it is calm. To ensure that electricity from such renewable energy sources is also available on still, dark winter days, it needs to be stored. Scientists from the Professorship of Renewable Energy Carriers at the Swiss Federal Institute of Technology (ETH) Zurich have researched such an innovative storage solution as part of a joint project.

In the Ticino Alps, researchers from ETH Zurich, the EPF Lausanne, SUPSI and the Paul Scherrer Institute, together with the company ALACAES, have tested a compressed air reservoir in an old tunnel under the leadership of Andreas Haselbacher. The principle: when more electricity is generated from renewable sources than is needed, it is used to compress air, a process similar to that of inflating a bicycle tyre. If there is too little electricity at a later time, you open the tire valve, so to speak, and the compressed air escapes, driving a turbine that generates electricity in the process.

At the pilot plant, the air is pressed into a cavern 120 metres long and 5 metres in diameter – this mountain cavity is a remnant of the construction of the Gotthard Base Tunnel. The cavity is closed off by two five-metre-thick concrete plugs and steel doors. Some 400 metres of rock tower above it. The researchers have demonstrated in this project that pressure can actually be built up here and that no air leaks through the rock.

Pumped-storage systems are not enough

Pumped-storage plants represent an alternative means of compensating for fluctuations in electricity production and consumption. Here, the excess electricity is used to pump water into huge reservoirs. Worldwide, such facilities account for 99 % of total storage capacity. However, the capacities for further plants are limited: room for reservoirs cannot be found everywhere and environmental associations object to the landscape degradation that accompanies such systems. In this respect, compressed air reservoirs are significantly more environmentally friendly as they can be built completely underground.

Nevertheless, existing compressed air storage systems in Germany and the US with an efficiency rate of 45 % to 50 % are much less efficient than pumped-storage systems with an efficiency level of 75 % to 85 %. The lower efficiencies of the existing compressed air reservoirs are due to the separation of the heat generated during the compression of the air. This heat needs to be fed back into the air before the turbines – otherwise they would freeze. This requires energy that is sourced from the combustion of fossil fuels – the existing compressed air reservoirs are therefore not only inefficient, but also not environmentally friendly.

For this reason, the researchers combined the compressed air reservoir at the pilot plant in Ticino with a heat accumulator. Part of this heat accumulator is an approximately ten-metre-long and three-metre-high concrete tank containing rocks. The rocks store the heat generated during the compression of the air. Later, when the compressed air reservoir is discharged, the compressed air from the cavern flows over the hot rocks and heats up again. However, this heat output is not constant. The temperature of the air that drives the turbines fluctuates over time and this affects their output.

Combined heat accumulator ensures stable turbine output

The solution to the problem was investigated in more detail as part of a sub-project: a so-called latent heat accumulator. This is a box with a depth, height and width of around one metre, which is connected to the concrete tank with the rocks. It contains steel pipes with a special metal alloy. This alloy becomes liquid when the compressed air with a temperature of more than 550 degrees Celsius flows over the steel pipes, and solid when the air is colder. The latent heat accumulator is important because it ensures that the air that escapes from the heat accumulator has a stable temperature.

In their pilot tests, however, the scientists found that during operation wear occurs inside the steel pipes of the latent heat accumulator. In a further sub-project, scientists from the EPF Lausanne led by Sophia Haussener investigated this wear and developed a protective ceramic layer that lined the steel pipes. This protection reduced wear by 90 %.

High efficiency achieved

In their project, the researchers were thus able to show that compressed air reservoirs are technically feasible in Switzerland and could also achieve a high degree of efficiency of 65 % to 75 % in combination with heat accumulators – in other words, they are almost as efficient as pumped-storage systems. In contrast to pumped-storage systems, they are located underground and therefore give rise to fewer reservations with regard to environmental and landscape protection. Another sub-project led by Maurizio Barbato of SUPSI has investigated whether compressed air storage power plants would really be more environmentally friendly and whether they would pay off on an industrial scale.

To this end, the researchers created a mathematical model of the power plant, including the turbines – the pilot plant only tested the compressed air storage and not the electricity generation by turbines. This model shows that a plant on an industrial scale with an output of 100 megawatts and a capacity of 500 megawatt hours is theoretically possible – at a cost of around CHF 110 million. However, the question of whether the construction and operation of such a plant would also be worthwhile for companies depends greatly on legal and political circumstances. Nevertheless, researchers led by Peter Burgherr at the Paul Scherrer Institute have shown that there are no major differences between pumped-storage and compressed air storage plants in terms of the extent to which they affect the climate and ecosystem.

Produkte aus diesem Projekt

- Pilot-scale demonstration of advanced adiabatic compressed air energy storage, Part 1: Plant description and tests with sensible thermal-energy storage
  Date of publication: 01.01.18
- Pilot-scale demonstration of advanced adiabatic compressed air energy storage, Part 2: Tests with combined sensible/latent thermal-energy storage
  Date of publication: 01.01.18
- Constrained multi-objective optimization of thermocline packed-bed thermal-energy storage
  Date of publication: 01.01.18
- Experimental investigation of the thermal and mechanical stability of rocks for high-temperature thermal-energy storage
  Date of publication: 01.01.18
- Combined sensible/latent thermal-energy storage: filler materials, feasibility at the pilot scale, and design method
  Date of publication: 01.01.18
- Toward a new method for the design of combined sensible/latent thermalenergy
  Date of publication: 01.01.18
- Druckluftbatterie in den Alpen
  Date of publication: 01.01.18
- Wie das Grundproblem der Energiewende gelöst werden könnte
  Date of publication: 01.01.18
- Druckluftspeicher in den Schweizer Alpen
  Date of publication: 01.01.18
- Druckluftspeicher: Der Gotthard hält dicht
  Date of publication: 01.01.18
- NFP 70 - Stromspeicherung über adiabatische Luftkompression
  Date of publication: 01.01.18
- Energie speichern mit Druckluft
  Date of publication: 01.01.18

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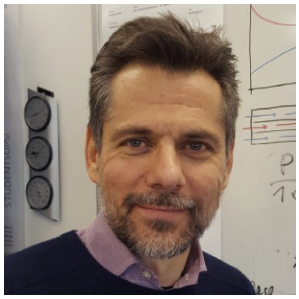
Project direction



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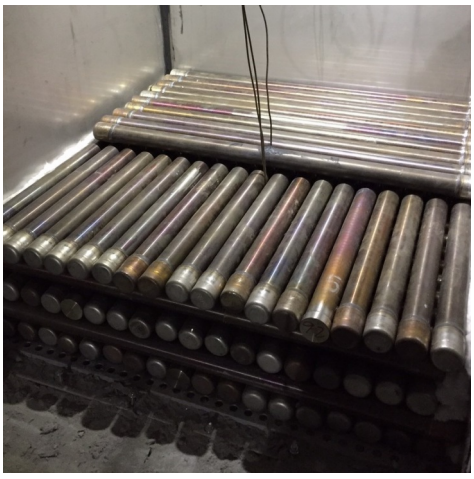
Connected projects

Optimising compressed air storage

Mountain Tunnels Store Compressed Air and Heat

Cycles of compressed air storage

Compressed air storage power stations represent efficient alternatives for electricity storage



New materials for compressed air storage

A Special Material for Particularly Efficient Novel Power Storage Systems

All information provided on these pages corresponds to the status of knowledge as of 10.05.2019.