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Demonstration of the ability of caverns for compressed air storage with thermal energy recuperation

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The authors only are responsible for the content and the conclusions of this report.

Project goals

The goal is the construction of a test plant to assess the feasibility of an advanced adiabatic compressed air energy storage (AA-CAES) system with thermal energy recuperation. For the test plant, a section of a dismissed tunnel excavated between Loderio and Pollegio (TI) for construction purposes of the Gotthard Basistunnel will be used and adapted correspondingly. The geological conditions of the selected tunnel section might be considered representative for the crystalline portion of the Swiss Alps. The aim of the pilot plant is to test and evaluate the design and operational conditions of the different plant components including the behaviour of the rock massif under cyclic charging/discharging operation. A future scale-up of the AA-CAES system could achieve efficiencies in the range of 75% and thus would be an attractive option to handle power fluctuations in the fast-growing electricity generation from wind and solar photovoltaics

Summary

ALACAES is realizing the world-wide first demonstration plant of the advanced adiabatic compressed air energy storage (AA-CAES) technology. In this technology, electric energy is used to run adiabatic compressors that deliver compressed air. During the compression stage, the air is heated up, which enters a thermal energy storage (TES) and is cooled down before it is stored in an air reservoir. When electricity is required, the compressed air leaves the air reservoir by flowing first through the TES and being heated up and is then expanded in a turbine that drives a generator. The incorporation of the TES eliminates the need for gas burners - which is required in conventional CAES plants - and increases the efficiency from 40% to above 72%. Further, the elimination of the gas burner reduces costs and eliminates CO2-emissions. For further information, please see www.alacaes.com.

The test plant is situated in a mountain in the southern Swiss Alps in Canton Ticino where the Blenio and Leventina valley meet, and exploits an unused tunnel dug for the transportation of the excavated material of the Gotthard tunnel. For the project, a track of 120 meters in the tunnel will be closed using two 5 m-thick concrete plugs, which will serve as the air storage reservoir and will also host the thermal energy storage.

The demonstration plant will focus on proving the general concept of the technology, most importantly the rock mass behavior under cycling of the pressurized air in the cavern, the air tightness of the rock and the concrete plug, and the performance of the TES in a pressurized area. The feeding is realized using a series of two isothermal compressors and a subsequent electrical heater that will simulate together an adiabatic compressor. Expansion is done using a controlled expansion valve where the flow characteristics are monitored in order to predict the performance for the future commercial plant.

Construction has started in June 2014 and so far the following works have been done: Installation of the safety measures at the tunnel portal for capturing leaking fluids, installation of the waste water pretreatment plant and connection to the communal sewage system; installation and commissioning of the 600 kW transformer; start of the longitudinal excavations in the tunnel for the placement of the tubes carrying signals, current, and water; start of the shotcrete and rock excavations for the installation of the main and secondary plugs.

Introduction

Fig. 1: The mountain where the Blenio and Leventina valleys meet, that hosts the demonstration plant.

The demonstration plant will be placed in a mountain in the southern Swiss Alps, where the Blenio and Leventina valleys meet (Fig. 1). The tunnel ends are in Pollegio on the west and Loderio on the east. It exploits an unused tunnel that has been dug to transport the excavated material from the Gotthard tunnel (Fig. 2).

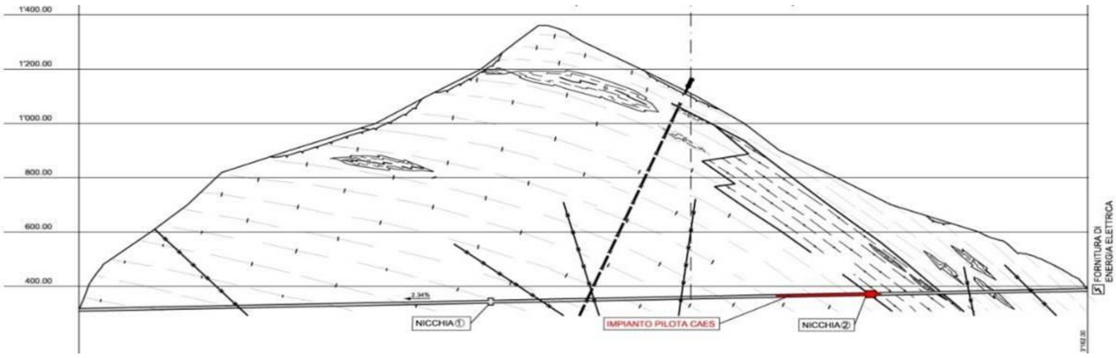

Fig. 2: Cross section of the mountain hosting the demonstration plant, indicating the position of the tunnel and the plant itself.

For the purpose of the demonstration plant, a track of 120 m in the tunnel will be closed using two 5 m-thick concrete plugs, which will serve as the air storage reservoir and will also host the thermal energy storage (Fig. 3). The turbomachinery consists of a series of two isothermal compressors and a subsequent electrical heater that will simulate together an adiabatic compressor. Expansion is done using a controlled expansion valve where the flow characteristics are monitored in order to predict the performance for the future commercial plant.

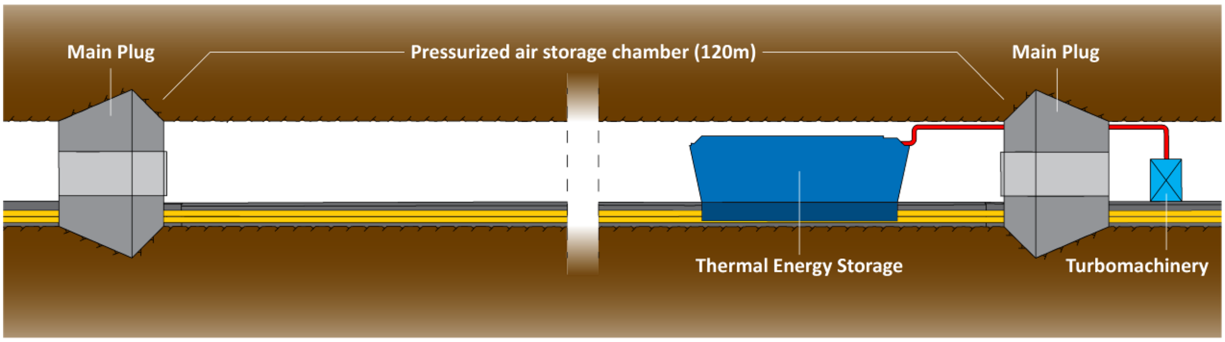

Fig. 3: Layout of the demonstration plant.

Completed tasks and achieved results

Construction has started in June 2014. Since then, the following tasks have been concluded/started:

1. Installation of leakage capture membranes at the Loderio portal

   In order to capture eventual leaks from the machines at the construction site, as a preventive safety measure, fluid capturing membranes have been placed 20 cm under the soil at the Loderio portal, which will be the access portal to the tunnel for the construction work (Fig. 4).

   

   Fig. 4: Fluid capturing membranes placed at the Loderio side of the tunnel. The membranes are later covered with approx. 20 cm of soil.

2. Installation of the waste water pre-treatment plant

   On the Pollegio side, a pre-treatment plant for the waste water of the construction site is installed and connected to the communal sewage system (Fig. 5). The pre-treatment plant consists of an oil separation basin and a sedimentation basin. All the water coming from the construction zone in the tunnel is guided through the pre-treatment plant and consequently flows into the existing sewage system. The mountain drainage water from the zones in the tunnel that are not affected by the construction, flows directly to the existing clean water canal, passing next to the Pollegio portal.

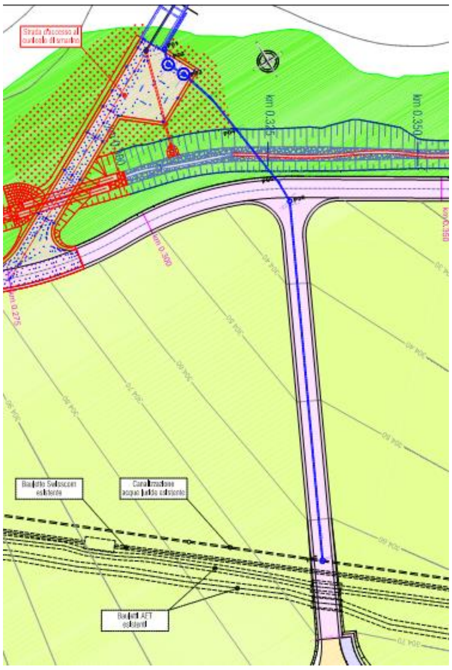

Fig. 5: Plant waste water pre-treatment installations and connection to the communal sewage system at the Pollegio portal. Left: Situation of the installations shown on map (indicated in blue). Right: Picture of the pre-treatment plant.

3. Installation and commissioning of the transformer

   The oil-free transformer, supplied by Azienda Elettrica Ticinese (AET), has been installed and connected to the grid (Fig. 6). It can supply a maximum power of 600 kW, and will be used to run the machines during the construction phase as well as the test phase.

Fig. 6: The 600 kW oil-free transformer supplied by AET.

4. Start of the longitudinal and transversal excavations

   Along the axis of the tunnel, in the zone of the demonstration plant, an 80 cm-wide excavation will be created where different tubes will be placed. These tubes will carry current, measurement signals, and drainage water. The cutting of the tunnel floor has been started. Further, the zones where the concrete plugs will be installed are also marked and will be excavated before the end of 2014 (Fig. 7).

Fig. 7: Left: Cutting the tunnel floor to subsequently dig and place the necessary tubes (water, current, signals). Right: Marking the exact position of the plugs using laser markers.

Besides the tasks introduced above, several components are being produced in parallel that will be installed in the tunnel, such as: two pressure bearing steel doors to be installed in the main plugs, fire resistant doors to be installed in the secondary plugs, concrete tiles to be used in the thermal energy storage, and other minor components. The geology monitoring devices (extensometers, geophone, pressure cells, strain gauges, etc) are ready and will be installed gradually with the progress of the civil works. The geology monitoring is carried out by Amberg Technologies.

National Cooperation

The project has already created national collaborations with two world-leading underground construction companies, namely Lombardi – Ingegneri Consulenti SA and Amberg Engineering AG that are shareholders of ALACAES. Azienda Elettrica Ticinese (AET) has expressed its interest in the project by supplying the transformer for free. Further collaborations are in the negotiation phase.

International Cooperation

The project has a high potential to help place Switzerland in a key position for the regulation and balancing of the European electricity grid. The increasing share of intermittent renewables, i.e. wind and solar PV, is posing challenges to the stability of the European grid. Hence, the necessity of large-scale storage technologies that can be used to handle the peaks in the electricity production from renewables is becoming more evident than ever.

ALACAES is in the process of signing an NDA with one of the world-leading turbomachinery manufacturers, that has expressed its interest in the technology.

ALACAES has increased its marketing activities by actively participating in relevant conferences, making memberships in energy storage associations, and seeking partnerships with promising enterprises.

Due to the innovative and promising nature of the technology, ALACAES has been invited to hold talks at several relevant conferences, such as the 3rd Israeli Energy Storage Conference, and ACI Energy Storage Conference 2015.

Evaluation 2014 and outlook 2015

The first half of 2014 was mainly dedicated to finalizing preliminary works on a technical, administrative and political level. After an initial delay in the start of the construction phase, the civil works have proceeded as planned.
It is foreseen to finish the construction of the demonstration plant by June 2015, after which the test phase will start for a duration of approximately 3 months.

References

Appendix
