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Isothermal Compressed Air Energy Storage (I-CAES) in Solution Mined Salt Cavern

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Abstract

The increasing share of intermittent renewable energy in the electricity generation mix presents new challenges for grid operators and regulators. One such challenge is extended periods of significant underproduction. Pioneers of the energy transition in the North Sea region have experienced numerous under-supply events, a phenomenon dubbed “Dunkelflaute” in German. During 2024, Germany experienced three Dunkelflaute periods, including one lasting several weeks in November, which drove wholesale electricity prices to as high as 92 [Eurocents/kWh]. The impact of these phenomena is likely to increase along with rising demand for electricity (due to data centers and electrification of heat and transportation) and increased renewable deployment (aiming to reach 80% renewable share by 2030).

Policymakers around the globe currently face the challenge of ensuring long-duration backup power through conventional generation methods. Investment in new fossil fuel power plants is uneconomic in many geographies due to high fuel costs, low load factors, and carbon pricing. To maintain energy supply continuity, policy makers will need to incentivize construction of new fossil fuel power plants and/or long-duration energy storage (LDES) technologies.

Given the extended durations and limited annual cycles, LDES technologies require extremely low-cost storage reservoirs. Compressed air energy storage (CAES) can utilize solution-mined salt caverns as such cost-effective reservoirs. Traditional diabatic CAES (D-CAES) methods require additional storage elements such as natural gas reservoirs and large heat exchangers, while adiabatic CAES (A-CAES) methods require thermal energy storage dedicated to compensating for inherent temperature changes throughout the compression and expansion processes. These technologies can increase the storage cost and in the case of D-CAES also pollute the environment. Isothermal compression and expansion processes can be employed to maintain a constant air temperature, thereby eliminating the need for thermal compensation.

In this paper, we present the AirBattery™, a novel isothermal CAES (I-CAES) technology, developed and demonstrated by Augwind Ltd. This system employs a series of underground water pistons to compress and expand air, using solution-mined salt caverns as the storage medium. The air is kept near ground temperature because the controlled, slow underground process facilitates efficient heat exchange between the air, the water inside the piston, and the surrounding earth.

An installed 250 [kW] / 1 [MWh] AirBattery™ demonstration facility is reviewed, along with the technology’s scale-up potential, including a high-level techno-economic comparison to other technologies in terms of round-trip efficiency (RTE) and capital expenditures (CAPEX).

Based on a first technical assessment, caverns seem to be a promising option for storage of large volumes of compressed air under high pressures. Being quite comparable to gas storage in caverns, and with the existing experience of storage of compressed air in caverns in Germany and the US, the development of an AirBattery™ demonstration project including a (small) salt cavern seems highly feasible.

Key words: Isothermal Compressed Air Energy Storage (I-CAES); Caverns for Gas Storage; Storage Caverns; Long-Duration Energy Storage (LDES); Germany; United Kingdom; Denmark; Netherlands; Dunkelflaute.