Compressed air power storage

Compressed air power storage

The growth of renewable power generation is experiencing a remarkable surge worldwide. According to the U.S. Energy Information Administration (EIA), it is projected that by 2050, the share of wind and solar in the U.S. power-generation mix will reach 38 percent, which is twice the proportion recorded in 2019. The incorporation of Compressed Air Energy Storage (CAES) into renewable energy systems offers various economic, technical, and environmental advantages.

By 2030, it is anticipated that renewable energy sources will account for 36 percent of global energy production. Energy storage systems will be instrumental in attaining this objective. Mechanical storage systems stand out among the available energy storage methods due to their reduced investment expenses, prolonged lifetimes, and increased power/energy ratings. Notably, commercialized large-scale Compressed Air Energy Storage (CAES) facilities have arisen as a prominent energy storage solution.

Since the late 1970s, (CAES) technology has been commercially available. This energy storage system functions by utilizing electricity to compress air during off-peak hours, which is then stored in underground caverns. When energy demand is elevated during the peak hours, the stored compressed air is released, expanding and passing through a turbine to generate electricity.

As per anarticle published in Energies, the CAES system follows the conventional three-phase model of a conventional gas turbine, encompassing charging, storing, and discharging.

In the charging phase, CAES makes use of off-peak and cost-effective electricity to compress ambient air. The compressed air is then stored in a dedicated pressurized reservoir, which can be either an underground cavern or an aboveground tank, typically maintained at a pressure of 40-80 bar.

During the discharge phase, the elastic potential energy stored in the compressed air is harnessed. The compressed air is drawn from the reservoir, heated, and subsequently expanded in a turbine train at high pressure and temperature. This expansion process generates electricity that can be fed back into the grid.

CAES technology encompasses different types, including adiabatic systems and diabatic systems. The key distinction between these configurations lies in how they handle the heat generated during the compression process.

The diabatic CAES systems are the first-generation technology. In these systems, ambient air is compressed using a compressor train. The compression process generates waste heat, which is then dissipated to the surrounding environment through intercoolers. During the discharge phase, fuel is combusted to heat the air before its expansion in the turbines. This combustion process allows for the generation of electricity during peak demand periods.

The adiabatic configuration of CAES has been under development since the late 1970s, aiming to address the limitations of diabatic CAES. This particular compressed air energy storage system focuses on effectively capturing and storing the waste heat generated during compression. The stored heat is then recycled to elevate the turbine inlet temperature of the compressed air during the discharge phase. As a result, the adiabatic CAES system aims to reduce or even eliminate the reliance on fossil fuels, offering a more sustainable energy storage solution.

The primary objective of I-CAES is to maintain stable compression and expansion temperatures of the compressed air during the charging and discharging processes, respectively. This is achieved by implementing a quasi-isothermal process.

On the other hand, supercritical CAES involves compressing the air to a supercritical thermodynamic state, where the waste heat generated during compression is recovered and stored in a thermal energy storage system. The compressed air is then liquefied and stored in a dedicated cryogenic tank. During the discharge phase, the liquid air is re-gasified, heated using the stored thermal energy, and subsequently expanded through a turbine train to generate electricity, which can be supplied back to the grid. This process has an efficiency of around 68%.