



Article

Thermodynamic Analysis of Three Compressed Air Energy Storage Systems: Conventional, Adiabatic, and Hydrogen-Fueled

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Abstract: We present analyses of three families of compressed air energy storage (CAES) systems: conventional CAES, in which the heat released during air compression is not stored and natural gas is combusted to provide heat during discharge; adiabatic CAES, in which the compression heat is stored; and CAES in which the compression heat is used to assist water electrolysis for hydrogen storage. The latter two methods involve no fossil fuel combustion. We modeled both a low-temperature and a high-temperature electrolysis process for hydrogen production. Adiabatic CAES (A-CAES) with physical storage of heat is the most efficient option with an exergy efficiency of 69.5% for energy storage. The exergy efficiency of the conventional CAES system is estimated to be 54.3%. Both high-temperature and low-temperature electrolysis CAES systems result in similar exergy efficiencies (35.6% and 34.2%), partly due to low efficiency of the electrolyzer cell. CAES with high-temperature electrolysis has the highest energy storage density (7.9 kWh per m³ of air storage volume), followed by A-CAES (5.2 kWh/m³). Conventional CAES and CAES with low-temperature electrolysis have similar energy densities of 3.1 kWh/m³.

Keywords: compressed air energy storage (CAES); adiabatic CAES; high temperature electrolysis; hydrogen storage; thermodynamics

1. Introduction

Large penetrations of wind and solar energies challenge the reliability of the electricity grid, due to their intermittency and uncertainty. Storage technologies are being developed to tackle this challenge. Compressed air energy storage (CAES) is a relatively mature technology with currently more attractive economics compared to other bulk energy storage systems capable of delivering tens of megawatts over several hours, such as pumped hydroelectric [1–3]. CAES stores electrical energy as the exergy of compressed air. Figure 1 is a simplified schematic of a CAES plant. Electricity is supplied by the grid to run the air compressors and charge the storage system. Waste heat is released during the compression phase. Air is stored for later use—often in an underground cavern. During the discharge phase, compressed air is combusted with a fuel, and expanded in a turbine (expander) to regenerate electricity. Currently, there are two commercial CAES plants in operation: Huntorf in Germany (since 1978) and McIntosh in USA (since 1991) [4]. Moreover, there are some smaller projects in operations or in construction and planning phases, most notably General Compression's 2 MW, 300 MWh project in Texas, USA and SustainX's 1.5 MW, 1 MWh project in New Hampshire, USA [5].

Thermodynamic Analysis Of Compressed Air Energy Storage

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