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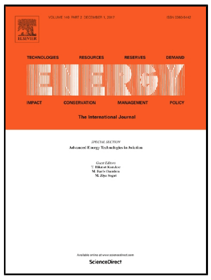

Detailed numerical investigation of a Pumped Thermal Energy Storage with low temperature heat integration

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Detailed numerical investigation of a Pumped Thermal Energy Storage with low temperature heat integration

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Abstract

In future energy systems, storage technologies for electrical energy are considered to be a key component for increasing the share of renewable energy use. Pumped thermal energy storage technologies represent a promising approach to complement established storage technologies such as pumped-hydro power storages without their geological restrictions. Assuming an ideal, reversible and adiabatic energy conversion process, the stored electrical energy can be entirely recovered. However, the efficiency of real processes is limited by irreversibilities. These exergy losses can be compensated by the integration of low temperature heat. The exergetic efficiency can be further increased by using thermal energy provided during discharging. In this paper, a fully heat-integrated, subcritical PTES using butene as the working fluid is presented. The results of a detailed numerical simulation of the cycle regarding exergy losses during heat transfer, efficiencies of machinery and parasitic energy consumption are shown. A maximum net electrical power ratio between charging and discharging of 125% is obtained, while the maximum exergetic efficiency is 59 %. The conducted numerical simulation includes pressure losses and pinch points, allowing for a more in-depth understanding and for a pre-optimization of the hydraulic design.

Keywords: Pumped Thermal Energy Storage, PTES, subcritical, ORC, butene, Power to heat to power, waste heat integration, ORC-CHEST

1 Introduction

One of the main challenges for increasing the share of renewable energy use is synchronising the availability to the demand. Storage systems fulfilling this task are often considered as a key element for the successful transition to a future energy system based mainly on renewable sources [1],[2]. Besides improving security of supply, storage systems can also increase cost effectiveness by avoiding curtailment of renewable energy generation during periods of low demand, thus maximising the utilisation of installed renewable capacity.

Energy storage systems have a long history of deployment to compensate for fluctuations in power demand. These storage systems make use of the variations in electricity costs, using low-cost electricity to charge the system while electricity is delivered during periods of peak demand. Today, almost all commercial systems for large-scale storage of electricity are based on one of the following concepts:

- Pumped-hydro energy storage (PHES): surplus electricity is used to pump water from a lower to a higher reservoir, thus increasing its potential energy. The water from the higher reservoir is used to operate a turbine to generate electricity during discharging. The worldwide generating capacity of PHES facilities is in the range of 130 GW [3].
- Diabatic compressed air energy storage (CAES): surplus electricity is used to compress air, which is stored in a reservoir. During discharging, air extracted from the reservoir is used to operate a turbine; fossil fuels are used to increase the turbine power and to avoid low air temperatures at the exit of the turbine. The total generating capacity of the two existing CAES plants is about 430 MW [4].

Both concepts are based on the internal storage of mechanical energy. Due to low volumetric storage density, natural storage reservoirs are required for a cost-effective implementation, which restricts the locations where such facilities can be built. In addition, the environmental impact of PHES plants results in lengthy project approval processes. The dependence on fossil fuel is considered a disadvantage for diabatic CAES for scenarios with a high share of renewable energy use. Currently, the most competitive technology is represented by electro-chemical storages with their known restrictions.