Topic: Compressed air energy storage

Title: Estimating the isothermal compressed air energy storage capacity for solution-mined caverns deployed in layered halite

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Indicate preferred mode of participation

Oral Presentation

ABSTRACT: (Maximum of 2 pages including the cover page using 11-pt Arial font).

Compressed Air Energy Storage (CAES) is a technology that stores surplus electric energy in the form of high-pressure air and releases it to generate electricity at peak time. Conventional diabatic CAES involves an inter-cooling technique and combustion of fossil fuels via gas turbines to heat air. He et al. (2017) derived the mathematical models of thermodynamic response when compressing air into a cavern at isochoric and isobaric modes and three heat transfer conditions between air and cavern wall including isothermal, convective heat transfer (CHT) and adiabatic conditions. Cai, Zhang and Guo (2022) developed a general-purpose subsurface flow simulator for modelling grid-scale hydrogen and gas mixture storage in caverns, deep saline aquifers and depleted fields. Dooner and Wang (2019) estimated the exergy storage capacity of 10 salt caverns located in the Cheshire Basin using Adiabatic CAES (A-CAES) and found that suitable scale and design of CAES system can minimize exergy destruction. Wang et al. (2017) reviewed the development of CAES technology including the thermodynamic characteristics of the energy storage system, the coupling of CAES with renewable energy and other issues. The Adiabatic CAES (A-CAES) uses indirect-contact heat exchangers and a thermal fluid to store the compression heat (Barbour et al., 2015). An interesting CAES scheme is the Advanced Adiabatic CAES (AA-CAES), which integrates a Thermal Energy Storage (TES) system to store heat generated from the compression process. Luo et al. (2014) introduced different types of CAES systems at different scales together with their challenging issues and future development.

In this abstract, a method has been proposed to estimate the theoretical CAES capacity under isothermal conditions. For isothermal air compression, the air temperature is constant, which could be achieved through a very slow air flow rate. This method is applied to estimate the Isothermal CAES (ICAES) capacity for solution-mined caverns deployed in layered halite in the Dorset area. The theoretical cavern deployment and cavern volume calculation in layered halite are implemented using the method developed by Parkes et al. (2018). Finally, the ICAES exergy capacity is calculated using the equations developed by Cengel and Boles (2005).

The structural surfaces of the top and base halite have been generated in the Dorset area from seismic data. These allow for a basin-wide assessment of the theoretical storage capacity to be evaluated. Following the method by Parkes et al. (2018) and Williams et al. (2022), a hexagon-close-packed theoretical cavern placement that covers the extent of the halite distribution area has been generated in the QGIS environment. The theoretical caverns are screened considering the geological conditions (excluding faults or halite thickness less than 50m) and surface infrastructure. In this modelling work, the cavern radius is set at R = 50 m. Each cavern must have a minimum wall thickness to ensure cavern stresses do not interact and cavern integrity is maintained. To ensure this, the cavern pillar width between caverns is set at 5R = 250 m. 3R (150 m) buffer zones are set to major roads, railways, rivers and water bodies. A 1000 m buffer zone is set to fault structures to maintain a stand-off distance in respect of the dipping angle of the faults. The initial cavern deployments are removed when they are located in the buffer zones.

Figure 1 shows the areas with maximum operating pressure exceeding 250 bars. The maximum operating pressure ensures the pressures remain within the engineering envelope for the cavern and leakage through the cavern walls does not occur. The value ranges between 253 bars and 451 bars. The estimated result indicates that 8609 caverns can be deployed with maximum operating pressure between (250-350) bars, with an exergy capacity of 7.643 TWh in the study area. 3447 caverns can be deployed with maximum operating pressure exceeding 350 bars, with an exergy capacity of 5.743 TWh, which leads to a total exergy capacity of 13.386 TWh.

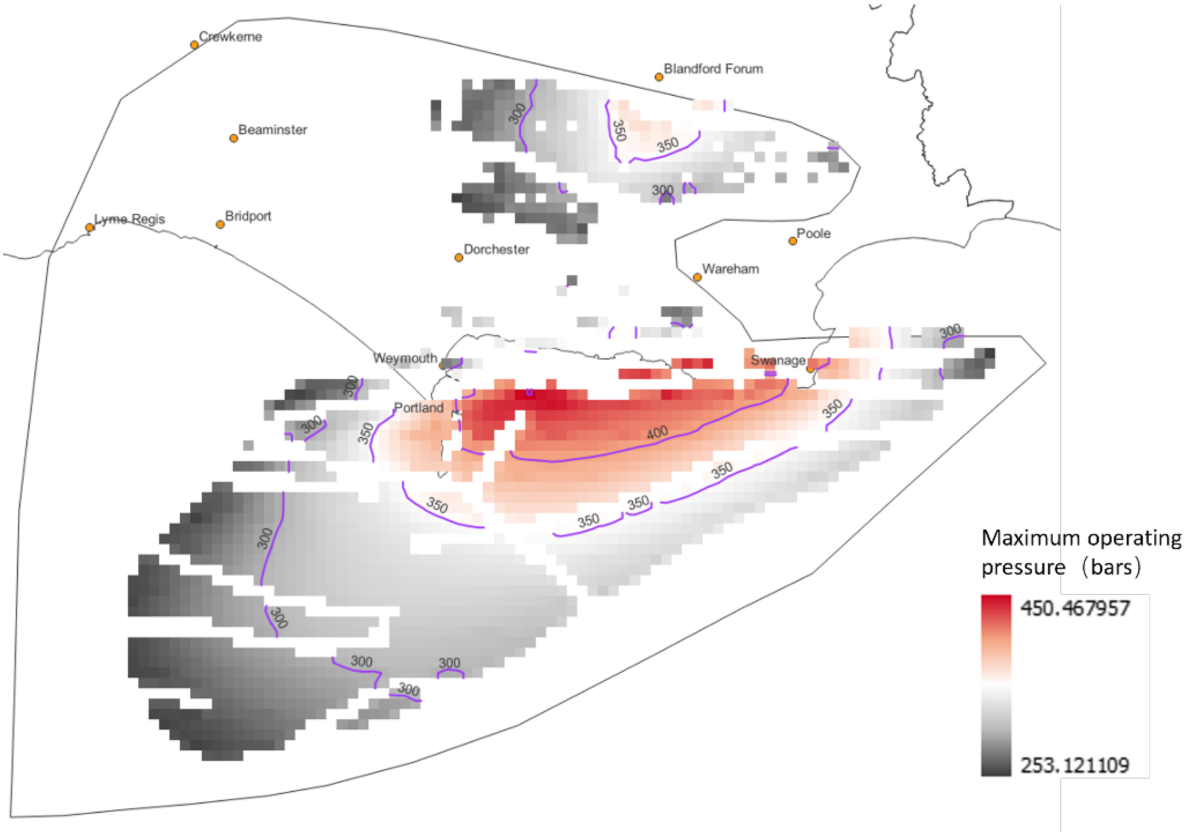

Figure 1. The colour map of the areas with maximum operating pressure exceeding 250 bars in the study area.