Contribution ID: **60** Type: **Contributed Oral**

C3Or4A-03: Novel concept of cryo-adsorbed hydrogen energy storage system

Wednesday 21 May 2025 16:45 (15 minutes)

The transition of the energy market to sustainable resources demands a variety of energy storage technologies. Existing systems propose energy storage from kWh to GWh levels, each with its strengths and limitations. The presented research proposes a novel energy storage method (patent pending) of cryo-adsorbed hydrogen energy storage (CAHES), aiming for large scale applications, in order of up to GWh and power outputs of a few GW. The main strength of the CAHES is low power consumption (high efficiency), in comparison with alternative existing technologies, mainly hydro pumped and compressed air energy storage. The technology can be implemented in any location, it doesn't need specific geographical conditions, and it has the potential for small dimensions and low-cost.

CAHES method consists of storing energy in adsorbed hydrogen at cryogenic temperatures, normally between 80 and 200 K, and pressures of a few tens of bars. CAHSE includes a compressor, which elevates the supplied hydrogen pressure to a higher value. The pressurized hydrogen flows through a thermal energy storage unit (TESU), where it is cooled down by emitting heat to the TESU. The pressurized cold hydrogen then expands at a cold turbine reaching its storage temperature and pressure. At this state the hydrogen is adsorbed in the adsorption cell and stored for a few hours, days or even weeks. When the hydrogen has to be provided it leaves the adsorption cell and flows through the TESU to extract heat from it. The warm hydrogen expands through a hot turbine to the required pressure, it flows again though the TESU, because its temperature is dropped again, and finally it is provided to the consumer. When all the possible hydrogen is provided, the remaining hydrogen in the systems serves for re cooling the adsorption cell, to be ready for an additional cycle.

A thermodynamic analysis of the cycle is presented, providing the energy consumption of the CAHSE, as function of the hydrogen storing temperature and pressure, system configuration, and energy storage duration. Calculated results show energy consumption of about 2 MJ per 1 kg of stored hydrogen, relative to published performance of existing compressed hydrogen energy storage systems, which consume at least 10 MJ per 1 kg of stored hydrogen. In addition, this paper presents two experimental plans, which are under construction in our lab, aiming for validating the numerical model of the cycle. The objective of one setup is to validate the hydrogen adsorption processes in the cell during the different cycle phases, and the objective of the second setup is to validate the TESU performances.

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Session Classification: C3Or4A - LH2 and LNG II: Storage and Utilization