Efficiency and flexibility potential by integrating water electrolysis in IGCC power plants for excess power storage

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The long-term transition to renewable energy systems will require flexible conventional power plants as well as energy storages in order to balance demand and fluctuating supply of wind and solar. For seasonal storage, Power-to-Gas is a promising opportunity. Electricity is converted to hydrogen by means of electrolysis followed by a conversion to substitute natural gas (SNG) with CO or CO₂. This offers high energy densities and the possibility to use the existing natural gas infrastructure (pipelines, storages) without further costs. The main disadvantages are high investment costs and a low power-to-power efficiency of 32%. In this context, the combination with an Integrated Gasification Combined Cycle (IGCC) power plant offers promising potential by using resulting synergies. Examples are the use of the by-product O₂ of electrolysis for gasification, avoidance of CO₂ sequestration for methanation and integration of the heat of the exothermal methanation. In the present work, flexibility, part-load efficiency and storage efficiency of IGCC storage concepts with high temperature electrolysis (HTEL) or alkaline electrolysis (AEL) and methanation are investigated. The analysis is based on detailed and validated models of the IGCC process by [1] in Aspen Plus and Ebsilon Professional as well as an empirical AEL model based on data of a 350 kW electrolyzer and a numerical model of the losses for HTEL. The advanced electrolysis models allow reproducing part-load behavior as well as temperature and pressure sensitivity. HTEL offers the potential to reduce the specific electrical energy consumption by 30% compared to AEL. The overall storage efficiency including reconversion of the produced SNG to power (η=0.55) is 48.5% (IGCC-HTEL). It is shown that the combination of IGCC and electrolysis has the potential to increase the efficiency of Power-to-Gas applications as well as the flexibility of the power plant with a superior operating range from +70 to -310 MW.

References