DETERMINING BEST VALUES OF OPERATIONAL PARAMETERS FOR REVERSIBLE SOLID OXIDE CELL SYSTEMS

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Motivation

In Austria the government declared in the mission 2030 ambitious plans for increasing mainly renewable electricity production and lowering the emissions of greenhouse gases. Already today our electric energy grid is facing huge challenges regarding the volatile nature of renewable producers like wind turbines and photovoltaic panels. Increasing renewable electricity usage will inevitably require a strengthening of electricity grids as well as novel energy storage solutions and a coupling between different energy carriers. Those storage and coupling systems can be integrated on different levels from household appliances and industrial systems up to centralized plants at utility scale. A reversible Solid Oxide Cell System together with a hydrogen storage can provide flexibility with different temporal periodicity and scale. Various different ideas for the system configurations have been already proposed in literature by various research groups [1–5]. It is widely agreed that a recirculation on the fuel gas side is advantageous. In our research we are investigating the implications of these different configurations for the efficiency and their suitability for the wide range of applications mentioned before.

Introduction to the study of reversible Solid Oxide Cell Systems

The system performance was evaluated on the base of two different configurations, cold-gas-recirculation and hot-gas-recirculation, which can be seen in Figure 1.

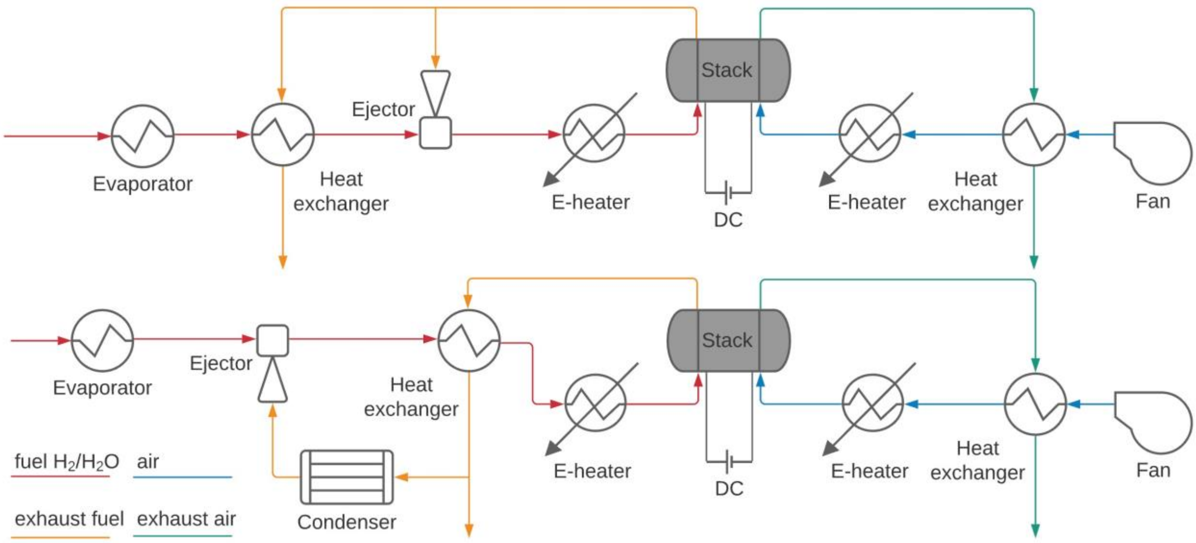

Figure 1 Basic system layouts, upper illustration with hot- and lower with cold-gas-recirculation

The main difference between both systems is, that with hot-gas-recirculation the ejector is working at the stack temperature and with cold-gas-recirculation the ejector and condenser operate close to the atmospheric boiling point of water. Furthermore, these temperature levels change between the fuel cell and electrolyser cell operation mode. In the electrolysis mode the fuel feed temperature after the evaporator, which can be seen on the left side in Figure 1, is always higher than the boiling temperature of water. As a result, there cannot occur condensation in the exhaust fuel leaving the heat exchanger. In fuel cell mode there is no such limitation. One identified influencing mechanism for the system efficiency is connected to the recirculation rate. Increased recirculation leads to a more homogeneous gas composition and temperature in the stack. Additionally, the fuel utilization is raised. On one hand both these effects increase the efficiency but on the other hand higher recirculation lowers the fuel

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concentration in the stack, which decreases the efficiency. In this presented research the behaviour and the influence of more parameters on the system efficiency were studied and quantified for various system configurations.

Methodology

For the investigation of the system performance, thermodynamic steady state simulation models were used, in which the stack behaviour is simulated by a semi-empirical model provided by AVL List GmbH. In the simulation we made parameter sweeps in a technically feasible range over: fuel utilization, volumetric recirculation rate, stack temperature, pinch point temperature differences of heat exchangers, subcooling temperature in the condenser and air flow in electrolysis mode.

The left graphic in Figure 2 allows us to conclude, that the most efficient operation with respect to recirculation rate and fuel utilization is given at high values for both parameters. Logging of all the relevant data during the simulation sweeps makes a detailed postprocessing possible and enables a deeper study of possible internal heat recovery measures as can be seen in the middle and right graph of Figure 2. Here the change of efficiency in the displayed region, with less than one percent, is nearly neglectable. This is caused by the previously described contrary mechanisms. Similarly, the behaviour can be studied in different system configurations. By comparing the results of different simulations the most appropriate design for specific applications can be determined.

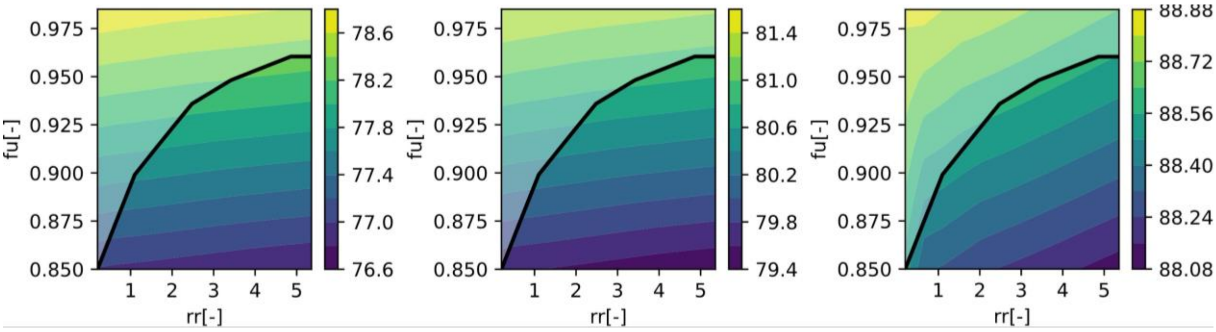

Figure 2 Dependency of system efficiency on the parameters volumetric recirculation rate (rr) and fuel utilization (fu) for (left) the case of providing high temperature and evaporation heat electrically, (middle) with recovery of waste heat from the air stream, (right) with recovery of waste heat and external heat source providing exergy for evaporation, greyed above black line: non-allowed stack operation

Outlook

Additionally, to the pure hydrogen operation mode, together with Forschung Burgenland and AVL List GmbH, a system capable of running with CH_4 in fuel cell mode is investigated. The application in buildings, industries and energy networks is addressed in the studies. All these research activities are happening in the context of the FFG funded project FIRST.

References

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