INTEGRATED HYDROGEN INFRASTRUCTURE DESIGN AND OPTIMIZATION: A CASE STUDY AT GRAZ UNIVERSITY OF TECHNOLOGY CENTER HYDROGEN RESEARCH

Teresa JAGIELLO[1], Markus KÖBERL[1], Markus SARTORY[1], Helmut EICHLSEDER[2], Christoph HOCHENAUER[3], Andreas WIMMER[4], Merit BODNER[5], Alexander TRATTNER[1, 2]

Introduction

Given the pressing challenges created by climate change, the necessity to transition energy systems becomes evident. Central to this transition is the application of cleaner and sustainable technologies, designed to minimize the environmental impact. For that transition hydrogen technologies play a central role because of their capacity to serve as a sustainable energy carrier, encouraging decarbonization, enhancing energy storage capabilities and enabling the integration of renewable sources. [1]

Objective

Research activities in the field of Hydrogen Technologies at the TU Graz has led to the implementation of highly sophisticated R&D H_2-research infrastructure at several institutes. Besides H_2-(Co-) fired industrial scale gas burner (1.5 MW), hydrogen fueled Internal Combustion Engines for mobile applications, industrial and maritime applications of up to 3.5 MW, gas turbine combustion chambers, Fuel Cell Testing Infrastructure for Single Cell-, Stack- and System Testing with a nominal power output of up to 160 kW have been implemented. Furthermore R&D Infrastructure for Electrolysis Testing from cell to small scale system level is in operation. These industry-oriented applications at different institutions at TU Graz within the hydrogen field serve as the foundational framework for the establishment of new hydrogen R&D-infrastructure at the same site. Therefore, test capabilities with an electrolysis test field for system testing at industrial scale (MW-level) will be implemented. The named applications result in complex and volatile demands for hydrogen, providing potential for research to interconnect hydrogen consumers and producers at TU Graz. Existing infrastructure with different storage, compression, distribution and gas analysis capabilities serves as nucleus for an interconnected intelligent laboratory for industrial scale hydrogen testing.

Combination of R&D applications at the campus result in a complex and volatile demand for hydrogen. Different pressure levels, mass-flows and hydrogen quantities for various have to be met. Required testing pressure levels varying from 1 bar up to > 700 bar, mass flows from 0.1 kg/h up to 150 kg/h and testing durations from 1 hour up to 24/7 testing hours.

Optimization and design objective for a new interconnecting hydrogen infrastructure is to maximize hydrogen demand coverage by intelligent management of production, storage, distribution, consumption modules with a forecasting logistic-concept.

Method

To cover the volatile hydrogen demand of the R&D-infrastructure a statistical approach was defined to create typical hydrogen consumption profiles. Therefore, all demand-requirements were initially collected and their occurrence probabilities were defined. Based on the data gathered 42 consumption profiles were identified. The consumption profiles were randomly distributed over the course of a year using a MATLAB-based script resulting in 20 typical expected profiles for hydrogen demand. Therefore,

[1] HyCentA Research GmbH, office@hycenta.at, www.hycenta.at;
[2] Institute of Thermodynamics and Sustainable Propulsion Systems (ITNA)
[3] Institute of Thermal Engineering (IWT), https://www.tugraz.at/institute/iwt/
[4] Large Engines Competence Center (LEC), www.lec.at
[5] Institute of Chemical Engineering and Environmental Technology (CEET), www.tugraz.at/institute/ceet/

boundary conditions, restrictions and limits had to be set to define the possible sequences of the 42 consumption profiles (e.g., maximal mass flow and pressure level, maximum operating hours, considering dependencies between consumption profiles, etc.). A hydrogen demand on low pressure level (< 80 bar) of 31,9 t/year, at medium pressure level (300 bar) of 13,7 t/year and at high pressure level (700 bar) of up to 4,7 t/a summing up to a total hydrogen demand of 50,3 t/year were defined. The results of the randomly distributed profiles were then implemented into a Simulink-based hydrogen infrastructure model that is able to adjust facility parameters, operation strategy, the storage management system, the hydrogen distribution and the logistic system (e.g., frequency of trailer delivery) related to the demand profiles while considering the techno-economic optimization of the hydrogen infrastructure. Therefore, a preliminary operating strategy for the model-based optimization process had to be defined for a fundamental hydrogen demand management. Priorities were set to maximize the coverage of hydrogen demand at a given infrastructure configuration. For the optimization process three implementation scenarios were predefined to take into account restrictions concerning space requirement, approval feasibility e.g., with respect to maximum stationary storage capacities (Seveso-Directive) especially to consider technical restrictions of commercially available systems and specifications of existing systems (e.g., compressor) at the TU Graz. Variations of technical configuration of the scenarios were done at low and medium stationary storage capacity and pressure.

Results

Under the predefined boundary conditions, a characteristically yearly consumption profile was created. The profile shows a maximum weekly hydrogen consumption of 1710 kg at low pressure level, 880 kg medium pressure level and 321 kg at high pressure level. Average hydrogen consumption was calculated at 613 kg/week at low pressure level, 265 kg/week at medium pressure level and 91 kg/week at high pressure level for the same consumption profile. 69 % of the hydrogen demand of the created profile was > 600 kg/week. The total consumption per year for this particular profile results in 50.4 t and in an average total hydrogen consumption of 2391 kg/week.

The results of the developed simulation tool for the demand coverage serve as the basis for the design of the hydrogen infrastructure, which, in turn, has been determined and optimized through simulation. It is crucial to highlight that the techno-economic configuration of the hydrogen infrastructure, while upholding approval feasibility, has been considered as well. Figure 1 shows the most relevant technical specifications of the optimized hydrogen infrastructure.

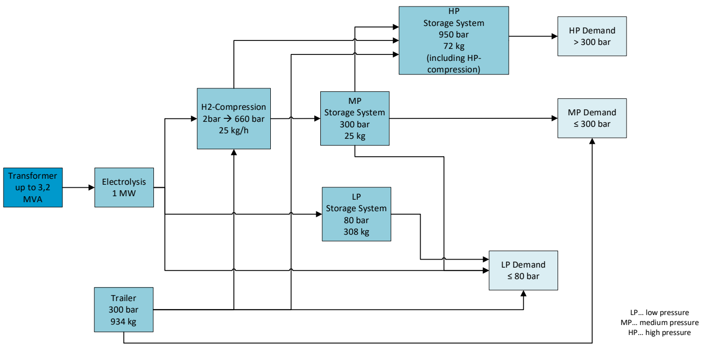

Figure 1: Scheme of the optimized hydrogen infrastructure model serving as basis for the real implementation

Conclusion and outlook

In conclusion, effectively navigating the challenges of volatile hydrogen demand within the unique context of TU-Graz underscores the viability and significance of intelligent solutions for the alignment of volatile on-site hydrogen production and hydrogen consumption. The presented Methods and Tools for infrastructure optimization are fundamental for designing decentralized small-scale to industrialized large scale hydrogen applications.

References

[1] Klell M, Eichlseder H, Trattner A. Wasserstoff in der Fahrzeugtechnik: Erzeugung, Speicherung, Anwendung. 4th ed; 2018.