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Assignment for project

Design of a feedback controller for a Power-to-Gas plant

Motivation: On the way to greenhouse gas neutrality by 2050, the expansion of renewable energies must be consistently driven forward. Therefore, renewable power from wind and solar plants is increasing. It leads to challenges such as balancing the fluctuations of renewable power. This is because, on the one hand, there will be times when electricity from renewables is abundant in the grid, and on the other hand, there will be times when electricity generation from wind and solar plants is insufficient to meet demand. The electricity grid has to be flexible enough to conquer this challenge and Power-to-Gas (P2G) system is an important component to achieve an efficient flexible grid.

Plant concept: The following figure shows the schematic structure of a Power-to-Gas plant. The plant consists of hydrogen production, storage, and methane feed-in to the natural gas grid. A commercially available 120 kW electrolyzer, which delivers 2-20 Nm^3/h of hydrogen gas, is to be designed for the course. The unused oxygen will be returned to the atmosphere and the produced hydrogen will be purified. The high purity hydrogen can either be used directly or stored in a hydrogen storage tank. The storage tank is operated in the range between 5 and 30 bar. In the Feed-in station, the hydrogen is converted into methane and can be fed into the natural gas grid. The volume controllers ensure that the state of the hydrogen storage tank is always within the permissible range.

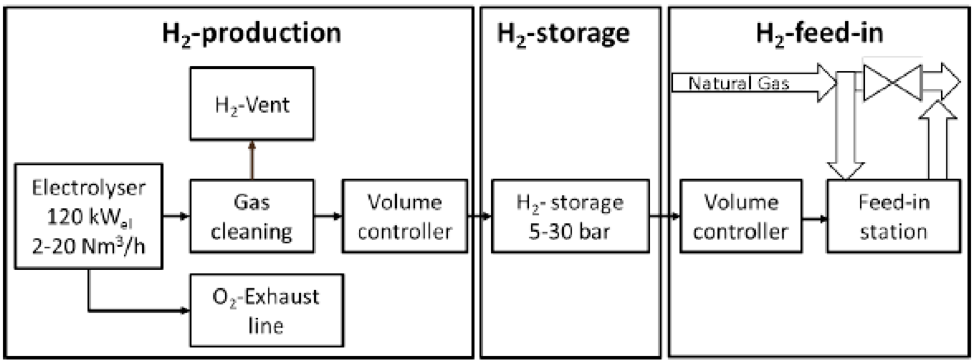

Figure 1: Schematic structure of the P2G test site at Fraunhofer ISE in Freiburg [1]

Task: Design a Power-to-Gas plant using the above specifications and 23 content points, which can be found on the last page. In addition, complete the following tasks as the main part of the project:

- Project management: Define work packages and a schedule with a Gantt chart showing the distribution of tasks within the project.
- Basic Engineering: Calculate roughly the dimensions of each component and draw a process flow diagram

[1] D. Fischer, F. Kaufmann, O. Selinger-Lutz and C. Voglstätter, „Power-to-Gas in a Smart City Context – Influence of Network Restrictions and Possible Solutions using On-site Storage and Model Predictive Controls“, *International Journal of Hydrogen Energy 43.20,* pp. 9483-9494, 2018

- Detail Engineering:
    - Electrolyzer: Describe different types of electrolyzers and select one that is best suited for P2G. Design the selected electrolyzer in detail. The system will include pumps, vents, and other components.
    - Gas cleaning: Choose, explain and design a suitable gas cleaning technology.
    - Feed-in station: In the feed-in station CO_2 and H_2 are converted to CH_4 in the methanation stage. The produced CH_4 is injected into the natural gas network. Design a reactor that can accommodate this process.
- Control Engineering: Design an ON-OFF controller based on the state of the hydrogen storage. The hydrogen is stored when the storage state is below a certain value. The methanation process is then activated when the storage is fully charged.
- Profitability analysis: Determine the operating and investment cost. Evaluate the profitability using the cash flow method.

Content points of the assignment

1. Title page with title, course of study, group members, matriculation number, start date, submission date, supervisor, professorship
2. Summary/Management Summary
3. Table of Contents
4. Tasks and objectives
5. Group structure, division of tasks, procedure
6. Timetable for the preparation of the work
7. state of the art
8. Description of the plant or apparatus to be planned, plant design
9. Plant diagram/process flow diagram of the plant according to DIN EN ISO 10628 with designation of the essential apparatus, machines and media.
10. Description of the system function
11. Brief description of the plant group, apparatus, machine within the plant
12. Prepared mass and energy balance for the plant and/or apparatus and machinery according to the task, using the necessary chemical, biological, reaction, thermodynamic, fluidic, thermal and material transport aspects.
13. Execution of experiments, analysis, results (optional if required)
14. Technical design and scale-up of the apparatus or machines according to the technical requirements such as turnover, volume/dwell time, pressure, temperature, pH value, ...
15. Technical design according to safety aspects such as material selection, corrosion, wall thickness according to e.g. AD 2000, gasket selection for flanges, bearing types of agitator shafts, insulation requirements, requirements for explosion protection zones, air exchange, ...
16. Technical design according to licensing aspects such as pollutant emissions in exhaust gases and exhaust air, noise emission, waste water pollution, ...
17. Overview of the prepared safety concept (HAZOP) with treatment of the essential safety aspects (Machinery Directive, pressure, explosion, machine) and solutions (according to product safety), indication of the method of safety assessment
18. Prepared technical equipment specifications with regard to technical design parameters, material specifications and other, e.g. production-related, special features and requirements such as welds and tests.
19. Derivation and presentation of a control concept with essential system-technical and safety-technical control loops in a piping and instrument flow diagram
20. Prepared media specifications of essential input materials, products and wastes with reference to the plant diagram, properties and safety
21. Capex and Opex calculation and economic evaluation by means of an economic efficiency calculation according to VDI 2067 or cash flow consideration.
22. Bibliography with reference to the most important literature, literature references in the chapters
23. Appendix with list of figures and tables, ...