OPERATION AND CONTROL OF A FLEXIBLE GREEN AMMONIA PLANT

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ABSTRACT

The production of green ammonia poses a significant challenge due to the variable nature of renewable energy sources. Addressing this challenge requires either large-scale energy storage or the implementation of flexible plant designs and operations. In practice, the latter approach presents a promising route for minimizing energy storage requirements and, consequently, capital cost. This project aims to investigate how a flexible green ammonia plant should be operated.

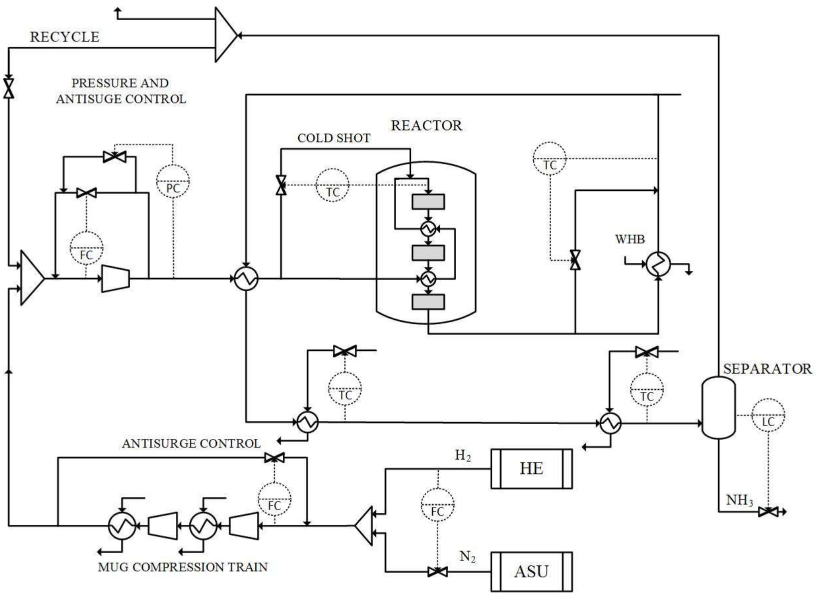

Figure 1: Possible process flow diagram of a flexible green ammonia plant. HE stands for Hydrogen Electrolysis, ASU for Ai Separation Unit, WHB for Waste Heat Boiler

In a conventional ammonia plant changing makeup gas load will affect the temperature and pressure. A flexible ammonia plant can be envisioned based on the process flow diagram depicted in Figure 1. This diagram illustrates several key adaptations to conventional plant designs to enhance flexibility and accommodate variable power production from renewable sources.

The nitrogen makeup gas flow rate is dynamically adjusted in response to varying hydrogen availability. Additionally, a novel pressure control system, suggested by Topsøe [1] and Casale [2], is integrated into the plant design to control the system pressure. The heart of the plant comprises a three-bed catalytic reactor with intercooling, wherein the reactor feed serves as the cooling medium [3]. Before entering the reactor, the feed undergoes heating in the feed effluent heat exchanger. Post-reaction, a portion of the heat generated is conventionally utilized for steam production, a practice retained in this design. To enhance the plant's adaptability, a temperature control system has been incorporated, which includes a bypass stream of the waste heat boiler and a cold shot stream to the first catalytic bed. The former allows for part of the reactor product to be directly sent to the feed effluent heat exchanger, circumventing the waste heat boiler. The latter directs a portion of the reactor feed directly to the first catalytic bed, bypassing the two internal heat exchangers. After the reactor, the mixture of ammonia, nitrogen, and hydrogen undergoes a cooling process to separate the ammonia from the unreacted gas, which is recycled, as in conventional ammonia synthesis. The cooling process is controlled with a temperature control mechanism. Furthermore, the compressors have been equipped with antisurge controllers.

Figure 1 is simulated dynamically using UniSim Design R492.
Some of the obtained results are shown in Figure 2 and Figure 3. Figure 2 illustrates the pressure and flow at the reactor inlet plotted against simulation time. It is evident that as the flow rate decreases, the pressure remains within ± 5% of the initial value. Figure 3 shows the temperatures in the reactor and the flow at the reactor inlet as a function of time. The depicted control strategy effectively maintains the desired temperature range under varying flow conditions.

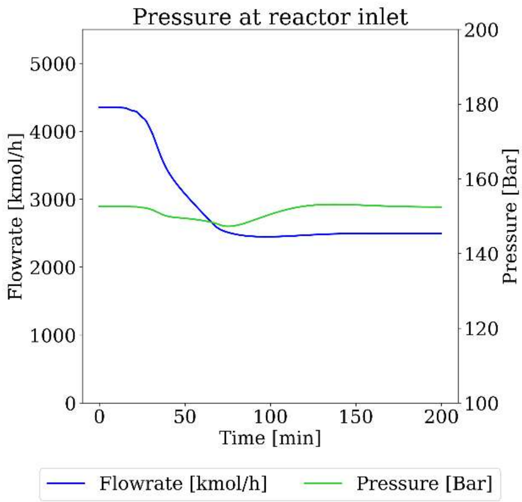

Figure 2: Pressure and flow at the reactor inlet plotted against simulation time.

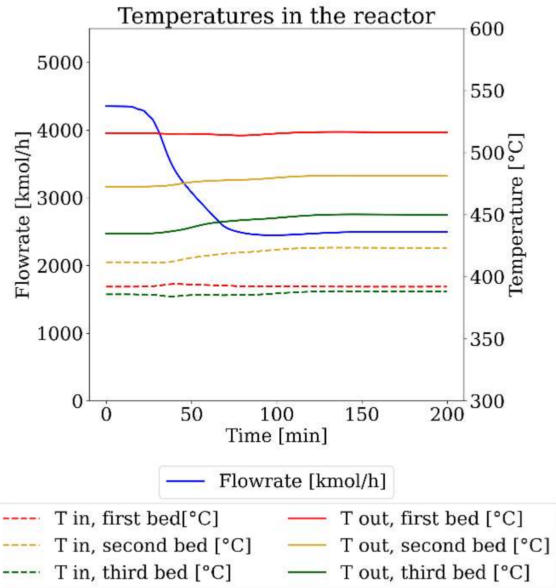

Figure 3: Temperatures in the reactor and flow at the reactor inlet plotted against simulation time.

These findings support the feasibility of transitioning to a flexible green ammonia plant by implementing an appropriate control strategy. Future efforts will focus on refining control parameters to optimize their effectiveness across a wider operating range.

References

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