A Systematic Plantwide Control Design Procedure for Load-Flexible Green Ammonia Plants using High-Fidelity Dynamic Simulations

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Abstract:

Power-to-ammonia (PtA) is gaining increasing attention as a promising route for renewable energy storage and transport (Olabi et al., 2023). Renewable ammonia can be synthesized from green hydrogen and atmospheric nitrogen via the well-established Haber-Bosch (HB) process. However, the intermittency of green hydrogen supply introduces significant operational challenges. In particular, HB plants must either rely on large hydrogen buffers or shift to dynamic operation with rapid load transitions over a wide range (Rosbo et al., 2026).
This work presents a practical procedure for plantwide control design of Power-to-X (PtX) processes characterized by strong nonlinearity and fast load changes. The proposed approach builds on established plantwide control design principles from Luyben et al. (1999) and Skogestad (2004). We adapt these principles to the specific challenges of highly load-flexible PtX systems, with strong emphasis on industrial implementability using proportional-integral (PI) controllers combined with standard control elements such as cascade, ratio, and feedforward.
The procedure is demonstrated on a high-fidelity, pressure-driven dynamic model of a realistic PtA process developed in AVEVA Process Simulation. Control system design is carried out sequentially through step-response analysis, relative gain array (RGA) evaluation at both full-load (100%) and low-load (10%) conditions, manipulated-controlled variable pairing, and PI tuning. The resulting control structure is subsequently enhanced with advanced control elements and validated through closed-loop simulations and ramping studies across the full operating range.
The results demonstrate stable and robust operation of the PtA process under rapid load changes. We show that the proposed control strategy successfully handles fast transitions without compromising process stability, suggesting that control limitations are unlikely to be the primary bottleneck for dynamic operation under intermittent renewable input. The study provides a systematic and practical framework for industrial plantwide control design of flexible PtX processes and highlights the potential of simple control strategies for robust operation under highly dynamic renewable input conditions.

Keywords: Power-to-Ammonia, Plantwide Process Control, Dynamic Simulation

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