Robust Nonlinear Control Design for a Multistage Hydrogen Compression and Intercooling System ⋆

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Abstract: Hydrogen compression is essential for storage and delivery in low-carbon industrial energy systems, but multistage compressor trains require reliable thermal regulation under uncertain operating conditions. This work proposes a robust nonlinear control framework for outlet-temperature regulation in a multistage intercooled hydrogen compression system. A control-oriented model combines quasi-static centrifugal-compressor performance maps, lumped dynamic heat-exchanger models, and interstage buffer capacities. For each intercooler, an input–output feedback-linearizing nominal controller is augmented with a continuous robust compensator based on projection decomposition of matched and unmatched uncertainties. The design accounts for biased or noisy temperature measurements and uncertain hydrogen mass flow, and a Lyapunov analysis establishes practical exponential stability of the temperature-regulation error. Simulations on a five-stage hydrogen compression train show accurate interstage temperature tracking, smooth coolant-flow control, and physically consistent pressure behavior under time-varying disturbances. Compared with benchmark robust and integral-action controllers, the proposed method demonstrates improved robustness and practical regulation performance.

Keywords: Hydrogen Compression; Intercooling; Robust Nonlinear Control; Input–Output Feedback Linearization; Practical Exponential Stability; Lyapunov method.

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