ANN-Based Adaptive NMPC for Uranium Extraction-Scrubbing Operation in Spent Nuclear Fuel Treatment Process

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Résumé

This paper addresses the particularities in optimal control of the uranium extraction-scrubbing operation in the PUREX process. The control problem requires optimally stabilizing the system at a desired solvent saturation level, guaranteeing constraints, adapting to disturbance rejection, and set point variations. A qualified simulator named PAREX was developed by the French Alternative Energies and Atomic Energy Commission (CEA) to simulate liquid-liquid extraction operations in the PUREX process. However, since the mathematical model is complex and is described by a system of nonlinear, stiff, high-dimensional differential-algebraic equations (DAE), applying optimal control methods will lead to a large-scale nonlinear programming problem with a huge computational burden. The solution we propose in this work is to train a neural network to predict the process outputs using the measurement history. This neural network architecture, which employs the long short-term memory (LSTM), linear regression and logistic regression networks, allows reducing the number of state variables, thus reducing the complexity of the optimization problems in the control scheme. Furthermore, nonlinear model predictive control (NMPC) and moving horizon estimation (MHE) problems are developed and solved using the PSO (Particle Swarm Optimization) algorithm. The MHE estimates the pertubations, thus correct the model for better predictions in MPC. Simulation results show that the proposed adaptive optimal control scheme satisfies the requirements of the control problem and provides promise for experimental testing.

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