Dynamic Optimisation of Alternating Activated Sludge Processes

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Objectives

- Nitrogen removal in single basin wastewater treatment plant.
- Solution method: dynamic optimisation.
- Determination of the optimal aeration policy (duration of the aeration and non-aeration sequences) which allows to minimise the energy consumption by the aeration system.
- Formulation of simple feedback rules.

Wastewater Treatment Plant Description

Influent Daily Variations

Optimal stationary trajectories with $J = 20$.

Optimisation Problem

Cost

Minimise aeration time over the period of one day

$$J = \frac{1}{T} \sum_{i=1}^{N} u_i (\pi = \frac{2\pi i}{T})$$

Constraints

- COD$_{\text{max}}$ $\leq 125$ mg/L Maximum effluent constraint on COD
- BOD$_{\text{max}}$ $\leq 25$ mg/L Maximum effluent constraint on BOD
- SS$_{\text{max}}$ $\leq 35$ mg/L Maximum effluent constraint on SS
- TN$_{\text{max}}$ $\leq 10$ mg/L Maximum effluent constraint on total nitrogen
- $u_i (j) \in [15, 120]$ min, $j = 1, 2N$ Constraints on aeration times
- $T = \frac{1}{u_i} \sum_{j=1}^{2N} u_i (j)$ Optimisation over one day
- $\|p - x(T)\| < \varepsilon$ Periodic stationary regime

Simulation Results

Simple Feedback Rules

Rule based control over several days. Left: Nominal and perturbed nitrogen constraint, right: nominal aeration policy. Perturbed conditions: 3rd day rainy with 100% increase of influent and 50% decrease of influent concentrations.

Results: in the long run, TN constraint only very slightly violated with average aeration rate close to optimal.

Conclusions

- Optimisation task defined and solved using the dynamic optimisation solver DYNO (www.ka.chtf.stuba.sk/fikar)
- Initial states considered as optimised parameters to obtain periodic steady state.
- Very satisfactory results with rule based feedback control
- Significant reduction of the total aeration time
- Results can indicate the relation between the actual and optimum operation and whether there is a room for improvement that will justify additional investments due to necessary sensors needed for state estimation.
- Stationary profile can be used as a setpoint at the existing plant or the simple rules observed here can be used to enhance the existing operating policies.

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