A Fast RTO Algorithm for the Optimal Operation of Slow Processes

R. Hernandez[1] and S. Engell[2]

Abstract: Model-based real-time optimization (RTO) is a well-known approach in the process industry for achieving economically optimal plant operation. The basic idea is to use a steady state model (usually nonlinear first principles based) in order to compute the operating points that optimize the economic performance of the process. This optimization is applied iteratively at long sampling intervals, typically hours, as after each change of the operating conditions one must wait for the plant to reach a new steady state. Despite its acceptance by the industry, especially in the petrochemical sector, there are several limitations of the approach. One of them is the fact that in the presence of model inaccuracies, the scheme will steer the process to a suboptimal operation, or to constraint violations. Moreover, the issue of having to wait for a steady state restricts the performance of the algorithm especially when it is applied to processes with long settling times.

In this work, a fast RTO scheme is proposed for the optimal operation of slow processes under model uncertainty. The idea of the approach is to integrate online system identification with a reliable iterative optimization algorithm in order to ensure fast convergence to the actual plant optimum despite the presence of structural plant-model mismatch. The addition of bias and gradients correction terms tothe optimization(called Modifier Adaptation) ensures that the first order KKT conditions are met. Using Quadratic Approximation of the plant response surface makes the estimation of the gradients less vulnerable to noise, leading to the MAWQA algorithm which is used in combination with the estimation of the steady state from the identification of the transient dynamics.

The performance of the proposed scheme is demonstrated for a novel chemical process, the hydroformylation of long chain olefins in a homogenous transition-metal catalyzed reaction in a thermomorphic solvent system. The process consists of a continuous reactor and a decanter to separate the outflow of the reactor into two phases so that the phase that contains the expensive catalyst can be recycled and the loss of catalyst is minimized. The recycle leads to long time constants of the plant. We show the efficiency of the new scheme not only in simulations but also in experiments at a miniplant. A significant improvement of the performance is achieved in comparison with an optimization that uses only the nominal rigorous plant model.

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[1] Group of Process Dynamics and Operations
Faculty of Biochemical and Chemical Engineering
Emil-Figge-Str. 70 (Einfahrt 10), 44227 Dortmund, Germany
{*reinaldo.hernandez, sebastian.engell*}*@bci.tu-dortmund.de*