



Figure 4.7 Hybrid model-predictive control framework for continuous crystallization.¹⁰⁶

A linear process model avoids problems typically encountered during non-convex optimization. Silva *et al.*¹⁰⁸ developed a linear MPC framework for a multiple-effect evaporative crystallizer. For such cases, in addition to constraints on the CSD, energy costs are a main driver for the economic performance. They used the slurry mass in each stage as controlled variable and temperature and brine flow rates were selected as manipulated variables. Step tests were used to construct a linear input–output model from a full nonlinear process model based on the moment equations and material and energy balances. A real-time optimizer (RTO) was used to send desired manipulated variables to the MPC, which needed to be achieved within constraints on the controlled variables. An economic objective function based on energy costs was used for the RTO. A Kalman filter was used as state observer. The performance of the MPC was compared to a scheme with conventional PID controllers. The MPC was able to achieve steady state much faster than the PID controllers and prevented oscillations in slurry mass, which could be seen when PID controllers were applied. Furthermore, the conventional scheme with PID controllers could not follow the optimal values informed by the RTO. Finally, this case also demonstrated the inherent benefit of MPC to include process constraints, for example, by limiting the maximum supersaturation to avoid excessive nucleation.

A current challenge for MPC is to take into account the impact of parameter uncertainties, model-plant mismatch and process perturbations. The reliability and prediction capabilities of the mathematical model depend, besides the model structure, on the quality and information content of the experimental data used for the parameter identification,