USE OF BACK-OFF COMPUTATION IN MULTILEVEL MPC

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Abstract — The desired operating point in Model Predictive Control is determined by a local steady-state optimization, which may be based on an economic objective. In this paper we propose the solution of a linear dynamic back-off problem to obtain a hierarchical scheme that ensures feasible operation in spite of disturbances. This is performed by computing the critical disturbances and expanding the optimization problem to ensure the existence of a control action that ensures the rejection of each perturbation.

Keywords — Model Predictive Control, Process Optimization.

I. INTRODUCTION

Model Predictive Control (MPC) refers to a class of computer implemented mathematical algorithms that control the future behavior of a plant through the use of an explicit process model. At each control interval the MPC algorithm computes in an open-loop mode a sequence of adjustments on manipulated variables, in order to optimize the future plant behavior under process constraints. The first input in the optimal sequence is injected into the plant, and the entire optimization is repeated at subsequent control intervals. In the modern processing plants the MPC controller is part of a multi-level hierarchy of control functions (Qin and Badgwell, 1997), as it is illustrated in Fig. 1. Several other authors (Richalet et al., 1978; Prett and Garcia, 1988) have described similar hierarchical structures.

The second stage of this hierarchy (the unit optimizer) computes an optimal steady-state point and passes it to the dynamic constraint control for its implementation. This desired operating point is usually determined by a local steady-state optimization, which may be based on an economic objective and a linear model. Typically, the resulting point lies at the boundary of the operative region (i.e., it is at the intersection of several active constraints, as many as the number of optimization variables). The underlying idea is that the controller provides perfect control, so that the plant remains at, or at least close to, its nominal operating point in spite of disturbances, parameter variations and uncertainty in the plant characteristics. This is a clearly unrealistic scenario, given that a practical situation a plant cannot be operated at its nominal optimum. A possible solution to overcome this practical limitation is to take a safety margin by strengthening the constraints (i.e., by reducing the feasibility region), and moving the desired operating point away from the actual plant constraints. In absence of information about how disturbances affect the steady-state point, this over design is hard to justify on economical grounds.

In this paper we present an alternative procedure to compute the operating point that guarantees feasible operation in spite of process disturbances. The main idea is to move the operating point away from the boundary of the feasibility region by considering the effect that the expected disturbances will have on the plant operation. This movement is referred in the literature as back-off. It was originally motivated by the desire of evaluating and comparing control strategies and process designs on the basis of their economic impact (Bandoni et al., 1994, Perkins and Walsh, 1994; Figueroa et al., 1994).

In general terms, the back-off problem consists in the optimization of a steady state objective function subject to dynamic constraints in the presence of process disturbances. Through this procedure, we ensure that the process operates at the optimal level of the defined performance objective function, with no constraint violations at the control level. In practice, the back-off problem is usually solved by finding an operative point that guarantees plant operation for the “worst case” of the disturbances, in the sense they produce the largest constraint violation.

Fig. 1. Hierarchy of Control System.