Model-Predictive Safety System for Predictive Detection of Operation Hazards: Off-Line Calculation of Most Aggressive Control Actions and Worst-Case Uncertainties

Abstract

In 2016 we introduced a method of model-predictive safety (MPS) system design [1]. The MPS system generates alarm signals that are predictive and systematically account for process nonlinearities and interactions, while typical existing functional safety systems generate reactive, non-interacting alarm signal(s) when a process variable exceeds a threshold, For the first time, the MPS system design method proposed a systematic utilization of the dynamic process models to generate predictive alarm signals (alerts) for the detection of present and future operation hazards (OHs) in real time. An MPS system uses a process model to project in real-time the process operability status and to generate alarm signal(s) indicating the presence of a present or future OH with reasonable accuracy; it generates predictive alarm signals that alert the process personnel to imminent and potential future OHs before the actual OHs occur. Although the method uses the concepts of moving-horizon, model-based prediction and state estimation, it does not implement any control; when an MPS system identifies a current or future hazard in the operation of a process, it indicates that no controller is or will be able to assure safe process operation. Compared to a first-principles MPC system, an MPS system is easier to implement, and its on-line computational cost is significantly less.

The implementation of an MPS system requires off-line calculations of (a) the most aggressive control action that minimizes each operability-constraint index when uncertain model parameters take their nominal values, and (b) the most aggressive control action that minimizes each operability-constraint index when uncertain model parameters take their worst-case values. After reviewing the MPS system design method, novel optimization methods that can perform the off-line calculations systematically will be presented. The performance and ease-of-use of the methods will be shown using chemical process examples.

[1] Mohseni Ahooyi, T., J.E. Arbogast, W.D. Seider, U.G. Oktem, and M. Soroush, "Model-Predictive Safety System for Proactive Detection of Operation Hazards," AIChE J., 62, 2024-2042 (2016).

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