# Fault tolerant model predictive control of exothermic reactions: Challenges and solution approaches

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**Abstract**

Model predictive control (MPC) is an attractive control scheme for embedding fault tolerance since, by being an optimal-control scheme solved online, it enables directly updating of the system model and constraints. Yet, there are several processes and systems where fault accommodation simply by updating the internal MPC model is infeasible. Of particular such interest is process plants with exothermic reactions. In order to avoid high temperatures while achieving profitable conversion rates, exothermic reactions may often be operated at an unstable steady state. A failure in an actuator may for unstable systems decrease the feasible area or reduce controllability, thereby rendering the MPC controller infeasible or preventing a transition to a safe and stable operating region. This may result in runaway of the reactions, destabilizing the process and possibly causing a hazardous fault situation.

To address the issue of recoverability from operating exothermic reactions at unstable steady states, we propose a proactive fault-tolerant MPC (FTMPC) scheme. The proactive approach seeks to utilize information about a slowly developing fault to actively steer the plant to a safe region before the incipient fault develops into a critical fault. The proposed FTMPC scheme relies on a switching from nominal economic operations to a safe-transition mode when receiving warning from a fault-detection unit about an incipient actuator fault. We design the proactive FTMPC controller within the framework of economic MPC, where we augment the safe-transition mode with an $\ell_1$ exact penalty term to steer the plant to a safe steady state where the suspect control actuator is inactive. This design results in a deadbeat control behavior of the safe-transition mode, thereby parking the plant at the safe steady state in a locally minimum number of timesteps. We further extend the proposed FTMPC scheme to account for time-dependent reduction of actuator capacity from onset of the incipient fault to eventual failure. We demonstrate application of the proposed FTMPC scheme through simulations of an exothermic continuous stirred-tank reactor.