Schriftenreihe des Lehrstuhls für
Systemdynamik und Prozessführung
herausgegeben von Prof. Dr.-Ing. Sebastian Engell

Band 1/2014

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Optimal Process Operation by Using Economics Optimizing Nonlinear Model Predictive Control

D 290 (Diss. Technische Universität Dortmund)

Shaker Verlag
Aachen 2014

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

Zugl.: Dortmund, Technische Univ., Diss., 2013

Printed in Germany.

ISBN 978-3-8440-2668-9
ISSN 1867-9498

Shaker Verlag GmbH • P.O. BOX 101818 • D-52018 Aachen
Phone: 0049/2407/9596-0 • Telefax: 0049/2407/9596-9
Internet: www.shaker.de • e-mail: info@shaker.de

Summary
Nonlinear model predictive control (NMPC) is perhaps the most advanced feedback control technique that introduced a significant impact on the industrial chemical processes since it is capable to optimize and control the system simultaneously. Its abilities to handle multivariable control systems, to incorporate constraints into the control problem formulation and to enable the integration of economics optimizing criteria into the feedback control design are the most outstanding advantages among many others.

Different nonlinear model predictive techniques were applied successfully to different control structures of a simulated nonlinear continuous stirred tank reactor with feed concentration disturbances and sensor noise, and to different control structures of a simulated pilot-scale continuous catalytic distillation column with plant-model mismatch and input and output noise. Both of the considered case studies exhibit complex phenomena such as nonlinearity, non-minimum phase behaviour (NMP), input multiplicity and local minima. Input multiplicities for instance may lead to multiple solutions and to wrong control actions and the steady-state may be shifted to a sub-optimal operating point during the operation of the plant when the standard class of controllers with a regulation objective (conventional reference tracking NMPC) is used.

Economics optimizing NMPC controllers to optimize and control the operations of a non-minimum phase continuous stirred tank reactor (CSTR) and the operations of a complex dynamics pilot-scale continuous catalytic distillation (CCD) process are intensively investigated. This direct economic optimization scheme is compared with a compromise scheme, the economics-oriented tracking controller. Different control structures are used to explore the potential benefits of the dynamic online economics-based nonlinear control strategies. Online state and disturbance estimation is an integral part of the investigated NMPC control schemes particularly in the presence of disturbances and plant-model mismatch. Two conceptually different state and disturbance estimation techniques are used in this dissertation namely the extended Kalman filter (EKF) and the nonlinear gain-scheduled observer, which is a modified version of the extended Luenberger observer (ELO).

In this dissertation, global as well as local optimization algorithms are used. The global optimization algorithm is used primarily to locate the optimal region (i.e. good initial guess) to a local optimization algorithm and to avoid those potentially optimal parts of the space from being overlooked. The local optimization algorithm finds the best point in that optimal region.

The outcome of this work indicates that by using direct economics optimizing NMPC the plant economics can be handled better while guaranteeing the product specifications. The economics-oriented tracking controller can also improve the economics of the process when more degrees of freedom than controlled variables are available, however, it can also violates the product specifications which necessitates the use of an extensive tuning procedure. Generally, the economics of the process can be enhanced when more degree of freedom are manipulated at the price of more complex optimization problems. The concept of the economics optimizing NMPC can straightforwardly be applied to similar chemical processes and the findings and conclusions deduced from this work are important for analogous chemical processes.