# BOOK REVIEW

## Predictive Control in Process Engineering—From the Basics to the Applications

*By R. Haber, R. Bars and U. Schmitz, Wiley-VCH, Weinheim 2011, 600 pp., $190,00.*

With origins dated back in the 1970s, Model Predictive Control (MPC) is now—at least for linear systems—a mature technology with more than 10.000 applications in the process industries world-wide. MPC provides an integrated solution for controlling multivariable systems with interacting variables, complex dynamic behavior and constraints for the manipulated and controlled variables (MVs and CVs). In contrast to other advanced control algorithms, MPC is able to deal with multivariable control problems having unequal numbers of MVs and CVs, or if the number of available MVs and CVs to be controlled change during the operation of the controller.

The term "Model Predictive Control" refers to a digital control algorithm that explicitly uses a dynamic process model to predict the future response of the controlled plant and take appropriate action through optimization. In the majority of industrial applications, a linear process model is used which is identified from plant test data. Until the 1990s, industrial MPC application was more or less restricted to refining and petrochemical industries. During the last decade, MPC was increasingly applied in other branches of the process industries including chemical, pulp and paper, cement and food industries. Due to increased computing power and more efficient optimization algorithms, sampling rates could be reduced to the milliseconds range, and as a result, nontraditional areas of applications (e.g., mechatronics) could be opened up. In recent years, MPC vendors spent a lot of effort to improve the usability of MPC packages. This includes more efficient identification tools, better integration of MPC with Distributed Control Systems, and monitoring MPC applications over time. As a result, not only control experts but also "average" chemical/mechanical engineers get involved in the design, commissioning and maintenance of MPC controllers in practice.

The book *Predictive Control in Process Engineering* is a contribution to better prepare (in particular chemical engineering) students and professionals for this new situation. After an introduction to the concepts and terminology of predictive control, Chapters 2 and 3 introduce different forms of single-input-single-output (SISO), discrete linear dynamic process models (FIR/FSR, discrete transfer function and state-space models), and their application for the prediction of the future system behavior. Chapter 5 treats in detail the generalized predictive control (GPC) algorithm for the SISO case for the unconstrained and constrained cases including measured disturbance feed-forward compensation. Much emphasis is given to the reasonable selection of the controller tuning parameters. In Chapter 7, MPC is generalized to the multi-input-multi-output (MIMO) case, which is of greater importance in practical applications. Here, the decoupling properties of multivariable MPC are treated in detail.

In contrast to other textbooks on MPC,[1,2,3] the reader will find chapters on predictive on-off control, predictive PID control and predictive functional control (Chapters 4, 6 and 11). In particular predictive functional control developed by Richalet[4] decades ago, has found wide industrial application for SISO applications.

With respect to nonlinear MPC approaches, the book includes Chapters (9 and 10) on linear, multimodel and multicontroller approaches and on GPC for block-oriented (Wiener-Hammerstein) and Volterra models. While the multimodel approach is standard in linear commercial MPC controllers, the other approaches still wait for packaging and a wider industrial application.

Up to 50% of industrial MPC project costs are caused by plant tests and subsequent development of dynamic process models. Therefore, it might wonder that the authors of the book decided to include only the rather short Chapter 8, concerning system identification. In my opinion, this decision is nevertheless justified. First, other sources about that subject are easily available, and second, including an elaborate system identification part would have overburdened the scope of a predictive control book.

It is a true strength of this book that the reader will benefit from a lot of exercises and simulations throughout all chapters. All numerical examples are calculated transparently step by step and in great detail which makes to follow the text easy even for newcomers in the field. Numerous helpful illustrations support the readability of the book. Moreover, the book includes a few case studies (injection molding and wastewater treatment control applications) in Chapter 12. It also contains descriptions of industrial scale MPC projects (distillation and furnace control in a refinery) which have been executed using commercial MPC packages (Chapter 13), and a "practical aspects/future trends" section. MPC practitioners will find here useful information about the different project steps to be executed, ranging from functional design and benefits studies to controller maintenance.

Based on the reviewers experience with MPC application in industry, the inclusion of some additional topics could have improved the usefulness of the text for industrial practitioners. First, only the traditional approach to unmeasured disturbance estimation is mentioned. More advanced disturbance estimators could have been discussed in the context of state-space model based predictive controllers. Second, most commercial MPC packages include an integrated steady-state optimization or target selection layer which in many cases contributes much to the economic benefit of advanced control (APC) projects. This two-layer (optimization and control) structure should at least be explained conceptually, including the mathematical solution by linear and/or quadratic optimization. Third, during the last decade nonlinear MPC algorithms not only underwent a fast development in control theory, but have also been applied in practice. In the process industries, NMPC applications are often based on rigorous and not on empirical models (e.g., in polymerization processes or in power plants). Therefore, NMPC based on differential-algebraic equation models and nonlinear state estimation would have been worth to be considered.

MPC theoreticians may miss a more detailed treatment of stability and robustness issues. Obviously, the authors have intentionally left these topics to other textbooks[3] and the technical literature, and for good reasons: the targeted audience will have a process engineering education with insufficient mathematical background to grasp easily the somewhat difficult MPC stability/robustness concepts.

Overall, the strengths of the books by far outweigh the open issues for the intended audience. The process engineering student and the APC practitioner will find and easy-to-follow but mathematically sound introduction to predictive control. The academician will find a wealth of information on MPC controller tuning, on reducing the computational burden of MPC algorithms, and on topics such as predictive on-off control, predictive PI control and PFC usually not being part of an MPC book.

In summary, I heartily recommend *Predictive Control in Process Engineering* to graduate students taking an advanced control course, to APC practitioners—in particular newcomers in the field—who seek a more detailed introduction to predictive control than just taking a course provided by one of the MPC vendors, and to process control instructors who will find a didactically sound and well-balanced text.

## Literature Cited


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