Training Course on Model Predictive Control (MPC) Theory and Application

Professional Development Training Course Outline

Category	Engineering	**Duration**	10 Days
Base Fee	$3,000 USD	**Delivery Mode**	Online / On-site Hybrid

Course Introduction

Introduction

Unleash the power of advanced process control with our intensive training course on Model Predictive Control (MPC) Theory and Application. Training Course on Model Predictive Control (MPC) Theory and Application delves into the sophisticated realm of optimal control, equipping participants with the knowledge and skills to implement robust and efficient control strategies across diverse industrial processes. MPC is a cornerstone of advanced process control (APC), enabling industries to achieve enhanced performance, increased efficiency, and improved safety by explicitly handling constraints, optimizing future behavior, and leveraging predictive models. This course emphasizes both the theoretical underpinnings and the practical deployment of MPC, addressing complex multivariable systems and various disturbance scenarios.

This comprehensive course is designed for engineers, researchers, and technical professionals seeking to master MPC for digital transformation and Industry 4.0 initiatives. We will explore cutting-edge topics such as nonlinear MPC, robust MPC, economic MPC, and integration with real-time optimization (RTO). Participants will gain hands-on experience with industry-standard software tools, enabling them to design, tune, and troubleshoot MPC applications for process optimization, energy management, and autonomous operations. Join us to be at the forefront of modern control engineering, driving significant improvements in operational excellence and sustainable industrial practices.

Programme Curriculum

Training Course on Model Predictive Control (MPC) Theory and Application

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Course Objectives

1. Grasp the fundamental principles and advantages of Model Predictive Control (MPC) over traditional control strategies.
2. Formulate linear and nonlinear MPC problems, including objective functions and constraint handling.
3. Develop accurate process models (e.g., state-space, transfer function, data-driven) suitable for MPC implementation.
4. Design and tune MPC controllers for single-input, single-output (SISO) and multiple-input, multiple-output (MIMO) systems.
5. Implement constraint handling techniques (e.g., input, output, rate constraints) effectively within an MPC framework.
6. Apply disturbance rejection strategies and manage uncertainties in MPC applications.
7. Explore and implement Robust MPC techniques to handle model-plant mismatch and unmeasured disturbances.
8. Understand the concepts of Nonlinear MPC (NMPC) and its application to complex processes.
9. Integrate MPC with Real-Time Optimization (RTO) for hierarchical control and economic benefits.
10. Utilize industry-standard MPC software tools (e.g., MATLAB/Simulink, Python libraries) for simulation and deployment.
11. Troubleshoot and diagnose common issues in MPC deployment and tuning.
12. Evaluate the economic and operational benefits of Economic MPC (EMPC) for sustainable operations.
13. Contribute to process optimization, energy management, and autonomous control using advanced MPC techniques.

Organizational Benefits

1. Significant Process Optimization: Achieving higher yields, better quality, and reduced waste.
2. Enhanced Operational Efficiency: Streamlined processes and automated decision-making.
3. Increased Energy Efficiency: Optimized energy consumption, leading to cost savings.
4. Improved Product Quality and Consistency: Maintaining tighter control over critical parameters.
5. Reduced Operating Costs: Minimizing material usage, energy, and downtime.
6. Safer Operations: Proactive constraint handling and disturbance management.
7. Competitive Advantage: Adoption of advanced control technologies for superior performance.
8. Skilled Workforce: Employees capable of designing, implementing, and maintaining cutting-edge control systems.
9. Faster Response to Disturbances: Mitigating the impact of unexpected process variations.
10. Support for Digital Transformation: Enabling data-driven decision-making and smart manufacturing initiatives.

Target Participants

- Process Control Engineers
- Automation Engineers
- Chemical Engineers
- Mechanical Engineers
- Electrical Engineers
- R&D Engineers
- Researchers and Academics in control systems.
- Operations Managers seeking to optimize industrial processes.

Course Outline

Module 1: Introduction to Advanced Process Control and MPC Fundamentals

- **Limitations of Traditional PID Control:** Addressing multivariable interactions and constraints.
- **Overview of Advanced Process Control (APC):** Context for MPC.
- **Introduction to Model Predictive Control (MPC):** Core concepts, predictive horizon, control horizon.
- **Advantages of MPC:** Constraint handling, multivariable control, optimization.
- **Case Study:** Simple temperature control system showing the need for advanced control.

Module 2: Process Modeling for MPC

- **First Principles Modeling:** Deriving dynamic models from physical laws.
- **System Identification Techniques:** Data-driven model building (step response, PRBS).
- **Linear Dynamic Models:** Transfer functions, state-space models.
- **Model Order Reduction:** Simplifying complex models for control.
- **Case Study:** Developing a linear model for a liquid level control system from experimental data.

Module 3: Linear MPC Formulation and Algorithms

- **Objective Function Design:** Minimizing errors and control effort.
- **Constraint Formulation:** Input, output, and rate constraints.
- **Quadratic Programming (QP) Problem:** The mathematical core of linear MPC.
- **Receding Horizon Principle:** Updating the optimization problem at each step.
- **Case Study:** Implementing a basic linear MPC for a SISO system in MATLAB/Simulink.

Module 4: MPC Tuning and Performance Evaluation

- **Tuning Parameters:** Weighting factors, prediction horizon, control horizon.
- **Performance Metrics:** Setpoint tracking, disturbance rejection, constraint violation.
- **Stability Analysis of MPC:** Ensuring closed-loop stability.
- **Robustness Considerations:** Handling model-plant mismatch.
- **Case Study:** Tuning an MPC controller for optimal performance on a simulated chemical reactor.

Module 5: Multivariable MPC (MIMO Systems)

- **Decentralized vs. Centralized Control:** When to use MPC for MIMO.
- **Interaction Analysis:** Identifying coupling between process variables.
- **MIMO Model Representation:** State-space models for multivariable systems.
- **Designing MPC for MIMO Processes:** Coordinated control of multiple inputs and outputs.
- **Case Study:** Applying MPC to a distillation column with multiple inputs and outputs.

Module 6: Constraint Handling and Optimization in MPC

- **Input and Output Constraints:** Hard and soft constraints.
- **Rate Constraints:** Limiting the speed of actuators.
- **Active Constraints Management:** How MPC handles constraints dynamically.
- **Feasibility and Infeasibility:** Dealing with unachievable targets.
- **Case Study:** Implementing an MPC controller with actuator saturation and product quality constraints.

Module 7: Disturbance Rejection and Feedforward Control

- **Disturbance Modeling:** Incorporating measurable and unmeasurable disturbances.
- **MPC with Disturbance Models:** Compensating for process upsets.
- **Feedforward Control in MPC:** Using known disturbances for proactive action.
- **Observer Design:** Estimating unmeasured states and disturbances.
- **Case Study:** Improving disturbance rejection in an exothermic reactor using feedforward MPC.

Module 8: Robust Model Predictive Control (RMPC)

- **Uncertainty Representation:** Bounded uncertainty, probabilistic uncertainty.
- **Min-Max MPC:** Guaranteeing performance under worst-case scenarios.
- **Tube-based MPC:** Designing invariant sets for robustness.
- **Stochastic MPC:** Handling probabilistic uncertainties.
- **Case Study:** Designing a robust MPC for a process with significant model uncertainties.

Module 9: Nonlinear Model Predictive Control (NMPC)

- **Challenges of NMPC:** Non-convex optimization, computational intensity.

- **Nonlinear Process Modeling:** Fundamental equations, empirical models.
- **Numerical Optimization Techniques:** Sequential Quadratic Programming (SQP), interior-point methods.
- **Real-time Implementation of NMPC:** Approximations and computational considerations.
- **Case Study:** Applying NMPC to a highly nonlinear pH neutralization process.

Module 10: Economic Model Predictive Control (EMPC)

- **Integrating Economic Objectives:** Cost minimization, profit maximization.
- **Formulating Economic Objective Functions:** Production rate, energy consumption, raw material costs.
- **EMPC vs. Regulatory MPC:** Direct optimization of economic performance.
- **Real-time Optimization (RTO) Layer:** Hierarchical control with EMPC.
- **Case Study:** Designing an EMPC for a power plant to minimize operating costs.

Module 11: MPC Software Tools and Platforms

- **MATLAB/Simulink for MPC:** Model Predictive Control Toolbox.
- **Python Libraries for MPC:** CVXPY, GEKKO, CasADi.
- **Commercial MPC Software:** Honeywell Profit Controller, Aspen DMCplus, Yokogawa Exasmoc.
- **Simulation and Hardware-in-the-Loop (HIL):** Testing MPC before deployment.
- **Case Study:** Simulating an MPC application using a chosen software platform and comparing results.

Module 12: Implementation and Deployment of MPC

- **Plant-Wide MPC Strategy:** Coordinating multiple MPC controllers.
- **Data Reconciliation and Gross Error Detection:** Ensuring data quality for MPC.
- **Operator Interface and HMI for MPC:** Presenting MPC information clearly.
- **Commissioning and Startup of MPC Systems:** Practical steps and challenges.
- **Case Study:** Planning the deployment of an MPC system in an existing industrial plant.

Module 13: MPC for Energy Management and Sustainable Operations

- **Energy Optimization in Industrial Processes:** Leveraging MPC for efficiency.
- **MPC for HVAC Systems:** Optimizing building energy consumption.
- **Smart Grids and Renewable Energy Integration:** MPC in power systems.
- **Reducing Environmental Footprint:** MPC for emissions control.
- **Case Study:** Designing an MPC to optimize energy consumption in a large-scale manufacturing facility.

Module 14: Advanced Topics and Research Directions in MPC

- **Distributed MPC:** Cooperative control of interconnected systems.
- **MPC for Hybrid Systems:** Combining continuous and discrete dynamics.
- **Learning-based MPC:** Integrating machine learning for adaptive control.
- **Event-Triggered MPC:** Reducing computational load.
- **Case Study:** Exploring a recen

Upcoming Scheduled Sessions

Start Date	End Date	Location	Price
23 Nov 2026	04 Dec 2026	Online	$2,000
23 Nov 2026	04 Dec 2026	Physical	$3,000
23 Nov 2026	04 Dec 2026	Physical	$6,000
23 Nov 2026	04 Dec 2026	Physical	$6,000
23 Nov 2026	04 Dec 2026	Physical	$12,000
23 Nov 2026	04 Dec 2026	Physical	$9,000
23 Nov 2026	04 Dec 2026	Physical	$12,000
23 Nov 2026	04 Dec 2026	Physical	$12,000

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