Advanced Process Control in ExxonMobil Chemical Company: Successes and Challenges

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Session 10B01: In Honor of Tom Edgar’s 65 Birthday II
Outline

• Process Industries Advanced Control Toolbox
• ExxonMobil Chemical’s Advanced Control Experience
• Engineering Specialists: Process Control
• Advanced Control Improvement Needs
• Tom Edgar’s Impact
• Summary & Conclusions
Process Industries Advanced Control Toolbox

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**Primary Function**

- **Closed Loop Multi-period economic**
  - **MPRTO** Multi-Period Real Time Optimization
    - Approximate nonlinear economic optimization over a time horizon
  - **RTO** Real Time Optimization
    - Provides economically optimal targets to LMPC
  - **LMPC** Linear Model Predictive Control
    - Stabilizes plant, push linearity to constraints
  - **PID** single input-single output control, multilevel cascade, surge margin
  - **DynOpt** Dynamic Optimization
    - Provides nonlinear economic optimization over a time horizon
  - **NMPC** Nonlinear Model Predictive Control
    - Provides combined nonlinear economic optimization and control
  - **Sequential** logic-based, discrete

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**Process Characteristic:**

- **Continuous**
- **Cyclic**
- **Semi-Continuous**

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Linear Model Predictive Control (LMPC)

- LMPC is the most widely used advanced control technology
  - Medium Size application routinely delivers significant energy savings as well as additional production
  - Example: Butadiene Recovery Unit, Baton Rouge Chemical Plant
    - 40 Manipulated Inputs, 50 Controlled Variables
    - Reduced steam consumption 12MBTU/hr ($800k/yr)
  - Example: “Typical” Ethylene Plant
    - 77 Manipulated Inputs, 189 Controlled Variables
    - 109 Additional Feed Forward Inputs
    - Energy Reduction / Feed Increase on similar scale

ExxonMobil Chemical
Real Time Optimization (RTO)

- Optimize the plant automatically on hourly basis by setting the underlying MPC setpoint
- Utilize real time price / cost information and plant constraints
- Cover all key unit operations in the plant
- Utilize rigorous thermodynamics and reaction kinetics to represent plant steady-state behavior
- Plant wide scope provides substantial benefits
Nonlinear Model Predictive Control

- Most ExxonMobil Chemical Company applications are first-principles based with some empirical elements
- Largest penetration of technology in polymers area
- Consistent control of properties through grade transitions is significant benefit of applications
- Modeling and parameter estimation require significant effort
- Little (if any) plant testing required

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Transition Amount (Klb) Probability

- NLC Transition Mean: 256.4 StDev: 21.9
- Operator Transition Mean: 342.8 StDev: 142.6
Engineering Specialists: Process Control

- Relatively Small Central Group
- Maintain expertise in supported technologies
- Support site projects and initiatives
- Provide higher level support for applications world-wide
  - Sites maintain significant expertise in supported technologies
  - Central group facilitates application updates, troubleshoots modeling and technology issues
- Keep up to date with “State of the Art Technology”
  - Collaboration with academic researchers to deliver proof of concept applications
  - Work with vendors to drive technology improvements to address issues discovered at manufacturing sites
Importance of Industrial Participation

• Actively contribute to professional societies
• Actively participate in joint academic / industry consortia
• Maintain a fresh perspective
  • Seminars from visiting professors
  • Support graduate student internships
• Actively participate in vendor user groups
• Collaborate with colleagues internally
Advanced Control Improvement Needs

- **Linear MPC**
  - Better control infrastructure design
  - Model consistency and closer integration to RTO
  - Identification tools that systematically enforce relationships between variables

- **Real Time Optimization**
  - Better NLP & MINLP solvers and parallel computing to handle large scale, mix-integer, and complementarity problem
  - Better understanding of distributed optimization & control

- **Nonlinear MPC**
  - Improved state / disturbance estimation methods
  - Parameter estimation
  - Improved integration of first principals and empirical models
  - Evolution to dynamic optimization
Tom Edgar’s Impact

• Education
  • Undergraduate – embraced new technology for course organization, teaching concepts, and working problems
  • Graduate – direct research of and maintain funding for a substantial research group
  • ExxonMobil has directly benefited from the quality of graduates produced

• Research
  • Over 250 refereed journal articles and significantly more conference publications

• Industrial Collaboration
  • Texas – Wisconsin – California Control Consortium
  • Making students available for internships and to work directly on problems of interest to industry
Summary & Conclusions

- Advanced control has been extremely successful applied to industrial problems
- Advanced control is not a “solved problem”, many research challenges still exist
- Ongoing academic and industrial collaboration is needed
- Maintaining capability to sustain applications is an ever present challenge
- Educators such as Tom Edgar are key to supplying the next generation of engineers with understanding of the technology and its capability
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