Enabling model based decision making by sharing consistent equation oriented dynamic models between multiple simulation and optimization environments

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Overview

Why do we need to use consistent models?

- How do we enable use of consistent models?
  - Common computational engine

- How do we enable consistent dynamic models?
  - Enhance common computational engine

- Sample results of the implementation
  - Dynamic batch distillation model in Aspen Plus
  - Custom dynamic tank model in Aspen HYSYS and Aspen HYSYS Dynamics
Model-Based Decision Making
Why Do We Need To Share Models?

• Consistent basis for making decisions
  – Reuse rigorous models.

• Reliability of the predictions

• Speed of deployment

• Better knowledge management
  – Standardized work process: Models created and maintained by a group; Distributed to all users
  – Lower cost. Reduces need to have experts at every site
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Consistent Model-Based Decision Making
Common Computational Engine

Plan
Schedule
Optimize
Control

ERP

Open Object Model Framework

Design & Support

Track
Monitor

DCS

Plant Operations & Engineers

Plant Operators & Engineers

Process Engineers

Schedulers

Planners
Consistent Model-Based Decision Making

Common Computational Engine

Engineering Solutions
- Aspen Plus
- Aspen HYSYS
- Aspen HYSYS Dynamics

Operations and Planning Solutions
- Aspen PIMS
- Aspen Refinery Scheduler

Open Model Executive (OOMF) “Backbone”

Model Providers
- Aspen Plus
- Aspen Custom Modeler
- Aspen HYSYS
- Aspen PIMS
- C++
- CAPE-OPEN
Consistent Model-Based Decision Making

Custom Steady State models can already be shared

• Since 2002 steady state models developed using Aspen Custom Modeler can be seamlessly integrated into process plant models in Aspen Plus, Aspen HYSYS etc.
  – Solve in Sequential Modular and Equation Oriented solution modes
  – Icons, tables, custom forms, Visual Basic scripts are exported and available in Aspen Plus, Aspen HYSYS
  – Model variables are accessible in design specifications, sensitivity calculations, calculator blocks
Consistent Model-Based Decision Making

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Rigorous Dynamic models can now be shared

- Author dynamic model in high level modeling environment
  - Aspen Custom Modeler
- Integrate the dynamic model with overall process model in
  - Aspen Plus and Aspen Plus Dynamics
  - Aspen HYSYS and Aspen HYSYS Dynamics
- Workflow enabled by common computational engine
  - Open Object Model Framework (OOMF)
  - Aspen Open Solvers (AOS)
Consistent Model-Based Decision Making

Aspen Custom Modeler
- Create rigorous dynamic model

Aspen HYSYS
- OOMF
- Rigorous dynamic model

Aspen Plus
- OOMF
- Rigorous dynamic model

Built-In Unit Operation Models
Consistent Model-Based Decision Making

OOMF – Common Computational Engine

Model Components
- C++
- ACM
- Legacy

Clients
- VB, C/C++, C#, Java

OOMF

Application Specific Extensions

Solvers
- LA
- NLA
- LP/MIP
- NLP
- MINLP
- Integrator
- Decomposer
Drive the dynamic model through time

- Start, pause, re-start, and reset
- Finite State Machine
  - Manage and control the multiple states from start to end
- Task manager
  - Load, activate, parse and interpret configured tasks
- Event Manager
  - Explicit events - step the simulation through time
  - Implicit events - conditions, actions, monitors
- Data historian
  - Record, View variable time profiles; Save snapshots
- Open Solver driver
  - Differential Algebraic Equation System object
Consistent Model-Based Decision Making
Aspen Open Solvers

Model Components
- C++
- ACM
- Legacy

OOMF

Application Specific Extensions

Solvers
- AOS Socket
- AOS Solver

- LP/MIP
- QP
- NLP
- MINLP
- LA
- NLA
- INTEGRATOR

- XPRESS
- DMO/SQP
- LSSQP
- MINLP
- MA48
- DECOMP
- DAE
- XSLP
- MA57
- SPARSE
Solve the dynamic model

- Aspen Open Solver Integrator
  - Explicit Euler, Implicit Euler, Runge-Kutta, Gear

- Interfaces and implementation for
  - Differential Algebraic Equation System Object
  - Group Decomposition
  - Tearing
  - Homotopy

- Event location
  - Discontinuities, Tasks

- Diagnostic Reports
Overview

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Results of the implementation

- Dynamic batch distillation model in Aspen Plus
- Custom dynamic tank model in Aspen HYSYS and Aspen HYSYS dynamics
Consistent Model-Based Decision Making

Results of the Implementation

Author the dynamic model in Aspen Custom Modeler.

- Create a dynamic model based on proprietary knowledge or chemical engineering literature
- Integrate dynamic model with overall process model in Aspen Plus and Aspen HYSYS.
- Two examples follow
  - Batch Distillation Model authored in Aspen Custom Modeler; integrated within an Aspen Plus process model
  - Custom tank model authored in Aspen Custom modeler; integrated within an Aspen HYSYS and Aspen HYSYS Dynamics model
Aspen Batch Distillation is a dynamic model developed using Aspen Custom Modeler. It is used for design, analysis, and optimization of batch distillation processes.
Consistent Model-Based Decision Making
Aspen Batch Distillation

- Developed using Aspen Custom Modeler
- Uses Aspen Properties
  - Rigorously model two-phase and three-phase columns
- Integrates a large DAE system
  - 1000 to 100000+ equations
  - Implicit Euler or Gear solution methods
- Uses tasks to model a sequence of batch operations
- Rich user interface for configuring column and operating steps
Consistent Model-Based Decision Making
Aspen Batch Distillation Sample Model

- Water-methanol separation
Consistent Model-Based Decision Making
Integration into Aspen Plus Via OOMF

• Aspen Batch Distillation Model now also available as a unit operation in Aspen Plus

• Integration with Aspen Plus enables simulation and optimization of:
  − Batch distillation sequences
  − Entire process including other batch or continuous unit operations
• Connect to other models and optimize the process
  – Notional buffer tanks at inlets and outlets
Consistent Model-Based Decision Making Integration into Aspen Plus Via OOMF

• Water-methanol separation using Aspen Plus
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Consistent Model-Based Decision Making

Custom Dynamic Tank Model
Consistent Model-Based Decision Making Integration into Aspen HYSYS Via OOMF
Dynamic models can be shared for better decision making.

- Author dynamic model in high level modeling environment
  - Aspen Custom Modeler
- Integrate the dynamic model with overall process model
  - Aspen Plus and Aspen Plus Dynamics
  - Aspen HYSYS and Aspen HYSYS Dynamics
- Improve process model accuracy, reliability and deployment.
  - Better knowledge management
- Workflow enabled by common computational engine
  - Open Object Model Framework (OOMF)
  - Aspen Open Solvers (AOS)
Consistent Model-Based Decision Making

- **Common Model Environment**
  - Enables use of consistent models in Engineering, Planning and Scheduling, Advanced Control, Optimization, and Operations

- Sample implementations of sharing of dynamic model in engineering were described in this paper.
  - The next paper will describe how similar models are used across Engineering, Planning and Scheduling, and Operations in the refining industry
Acknowledgements

• Ashok Bhakta
• Gabriel Lopez-Calva
• James Fielding
• Ajay Modi
• James Goom