Drive Profitability to New Heights with Our Most Innovative Approach to Optimization Yet

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Agenda

1. What is Advanced Process Control?
2. Profit Suite Overview
3. How is Honeywell advancing optimization?
4. The UOP connection...
5. Case Study
Advanced Control – What’s It all About?

• Advanced control and optimization is key to running process plants reliably, efficiently and responsively
• Typically projects give payback time of < 1 year
• Wide range of methods available
  – Pick the right one for the job
    ♦ Cost vs benefit

[Diagram showing variable, constraint limit, time, poor control, good regulatory control, advanced control]
Feedback control versus Model based control

Feedback Control must have an error to correct

Feed-forward control corrects based on guidance and error

Model based control corrects for future errors
Honeywell’s Advanced Control Solutions

- Profit Controller
- Profit Stepper
- Control Performance Monitor
- Profit Sensor Pro

Past

Future

Optimal Response

Setpoint

CV

MV

Assumed Values

Predicted Unforced Response

Optimal Response

Setpoint

CV

MV

Control Funnel

Optimal Response

Setpoint

CV

MV

Optimum

Optimum Operation

Dynamic Optimization

Profit

Current Operation

Additional $ Benefits

Wait for Steady State

Steady-State Optimization

Time
Profit Suite

• One Consistent technology platform
  – MPC and Real Time Optimization
  – Flexible Modeling environment
  – Unmatched operational awareness
  – Lowest lifecycle cost

Profit Loop → Experion Profit Controller (C300/ACE) → Profit Suite
- Profit Controller
- Profit Sensor
- Profit Stepper → Profit Optimizer
(DQP Multi-Unit Optimization) → Profit Executive
(SuperDQP Multi-Asset Optimization)

Continuum of Control Solutions
Single Variable Linear Control → Multiple-Variable Non-Linear Control and Optimization

Seconds → Hours/Days
Assumptions

• Working knowledge and understanding of APC

• Improvements in existing control and optimization layers is possible
  – Better control within each unit
    • Profit Controller
  – Better coordination of production units
    • Profit Optimizer
  – Improved control of inventory and final product quality
    • Profit Executive
## Small scale vs. Large Scale Optimization

### Single Unit
- Smaller scope of optimization (i.e. Single Unit)
- May not achieve full optimization benefits if upstream unit optimization results in downstream constraint violations
- Easier to solve because of smaller scope (10-20 independent variables, 50,000 equations)
- Traditional scope of most optimization applications

### Multi-Unit
- Larger scope of optimization, (i.e. Multi-Unit)
- Achieves greater optimization benefits because unit interactions considered, resulting in global optimum
- More difficult to solve because of larger scope (50-100 independent variables, 200,000+ equations)
- Current focus of optimization and base of wider scope development

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<thead>
<tr>
<th>Local Optimization</th>
<th>Multi-Unit Optimization</th>
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<tbody>
<tr>
<td>Process Unit</td>
<td>Process Unit 1</td>
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<td>Process Unit 2</td>
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<td>Process Unit 3</td>
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</table>
Honeywell Layered Optimization Solution

Pursuing Profit with Profit Optimizer

- Intermediate stream pricing
- Downstream unit constraints
- Cross unit opportunities

Solution
- Profit Optimizer continuous dynamic optimization
- Uses MPC model base in higher level optimization
- Manages final product quality and volume based on pricing
- Links downstream constraints

Enhanced Benefits Capture
Business Level Optimization

• Mega-Scale Optimization Support
  – Site-wide and/or Multi-site
  – Tiered Optimization (“Profit Executive”)
    ♦ Planning Integration & Schedule Management
Refinery Model – An APC View

APC model has a greater resolution but limited scope

- It captures essential unit or area operating constraints
- Optimizes unit production to possible detriment of plant
The model has a high level of abstraction

- It captures essential material and energy balances in holistic view of the refinery
- It leaves out many unnecessary or even obscuring details for the economic optimization
Can we bridge the gap between planning/scheduling and control?

Supply Side (upstream supply chain)
- What Feed to buy?
- Generate a month-plan based on an average model

Customer Demand (downstream supply chain)
- What products to sell?
- Daily delivery average

Monthly Planning
- Raw Materials → Execution → Products
- Monthly Planning
- Real Plant
- Models/Predictions

Weekly Schedule
- Feed Received
  - What Feed to use?
  - A set of production activities (e.g., receipts & blending activities)
  - Translate the plan into production activities to satisfy the plant logistics
  - Control and Optimize to the targets but only on a “best efforts” basis

Optimizers (DQP)
- Blending/shipping activities
- Product to be Shipped

Controllers (RMPCT)
- More effective in dealing with model errors and unplanned events (as a control problem)

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Planning – Execution Gap

Plan

- Planner uses aggregate yield models to predict product makes for raw materials.
- Planning model required to make complex decisions for which raw materials to purchase and which product to produce.
- Detailed unit model is generally not required and can lead to deleterious effects for solver.

Execute

- Current plan may be infeasible for current operating conditions.
- Today's yields may not match the planner’s yield model resulting in different operation.
- Mismatched operation can lead to imbalances in plant inventories.
- Assumed planning constraints for unit performance may be too aggressive or too conservative compared to actual performance.
General Operational Assumptions/Queries

• Planning models (LPs) are generally run (at most) once per day
  – Small corrections – scheduling and logistics

• Planning models do not incorporate current limits and current operating conditions within the plant
  – No Guarantee of the solution honoring the low-level constraints within all the units

• Feedback to improve planning from operational results comes through a person
**Key Challenge:**

How to get the solution layers to stay consistent and reach the global optimum jointly?

- **Business Planning**
  - Plantwide economics

- **Production Planning**

- **Schedule & Optimization**

- **Optimal feasible**

- **Control & Optimization**
  - Local economics

**Integration Scheme? How?**

Manage intermediate and final:
- Inventory (volumes)
- Properties (quality)
- Timeline (just in time)

**Real Time Dynamic Optimization - DQP (hr)**

**Planning (Months)**

**Scheduling (Day/Weeks)**

**App -1**

**App -2**

**App -3**

**App -n**
Example of planning seed yield model (structure)

<table>
<thead>
<tr>
<th>MVs CVs</th>
<th>Crude Feed 1</th>
<th>Crude Feed 2</th>
<th>FCCU Feed</th>
<th>FCCU RiserTemp</th>
<th>Hydrocraker Feed</th>
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- The overall gain matrix can come from a seed model.
- Additional CVs/MVs/DVs may be added depends on the SuperDQP control/optimization needs
- Note: Each gain element may be a product of multiple concatenated unit yields
The control model is derived from the planning model

<table>
<thead>
<tr>
<th>CVs</th>
<th>MVs</th>
<th>Crude Feed 1</th>
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- Concatenated (or convoluted) dynamic models are plotted above.
- Cascaded model structures (like bridge models) will be provided later for easy dynamic modeling.
- The model above has a structure that is identical/similar to that of the refinery’s planning seed model.
  - For each unit, a yield validation block will measure the actual yield and update the model gains.
High-level Structure of Profit Executive

A copy of yield model + economics from planning/scheduling

Returned values can include the predicted yields and proxy limits

Master Optimizer

Master MPC Controller

DQP -1

DQP -m

App 1-1  App 1-2  App 1-3  App 1-n

App 2-1  App w-1

App m-1  App m-p
Profit Executive Components

Planning

- **Optimizer**
  What-If steady state analysis using current operating conditions
- **Controller**
  Dynamic operating plan moves provided to simulator

Execution

- **Optimizer**
  Generates optimal steady state operating plan based on actual costs
- **Controller**
  Moves plant toward optimal while accounting for immediate constraints
- **Predictor**
  Computes yield/property model biases using operating data
- **APC Extensions**
  Bounds optimization problem based on APC constraints
UOP - HPS Integrated Solutions

UOP and HPS enable refiners to meet the challenges –

• lowering costs
• reducing risks
• improving efficiency
• providing and maintaining the newest and best infrastructure
• driving profitability

UOP - HPS Integrated Solutions

• Advanced Solutions enable safe and efficient operation of complex technology

• Advanced Solutions to optimize unit performance

• Advanced Solutions leverages process expertise to drive optimization

Performance Services
Operator Training
Asset and Abnormal Situation Management
Advanced control and optimization
Secure process control

World class in process design, process expertise

Enhanced Benefits Captured
UOP-HPS Integrated Solutions for APC

• UOP Process and Equipment Models
  - Fired heater simulation
  - Regenerator operation
  - Reactor severity (RONC / % Aromatics), conversion
  - Product yield and property models
  - Coke production, deactivation models
  - Real-time data collection and data analysis

• Refining
  – Catalytic Reforming - Platforming
  – Hydroprocessing – Unionfining, Unicracking, Uniflex
  – FCC / Alkylation – HF Alkylation
  – Light paraffin isomerization – Butamer, Penex

• Petrochemicals
  – Aromatics – Tatoray, Isomar, Parex
  – Detergents – LAB, Detal
  – On-purpose propylene and butylene – Oleflex

• Extendable beyond refining and petrochemicals

Models Meeting All Needs
UOP-HPS Integrated Solutions for APC
Process Models Example - Hydrocracking

**Process Data**
- Feed, internal and product stream rates
- Pressures
- Temperatures
- Cycle history
- Catalyst loading, volumes, density

**Lab Data**
- Gas stream compositions
- Feed, internal and product physical and chemical properties
- Product qualities, if available

**On-Line Analyzers**
- Mass balance
- Catalyst space velocity
- Catalyst life
- Hydrogen partial pressure
- Catalyst average bed temperatures
- %HDS, %HDN, gross and net conversion
- H2 consumed; atomic H balance
- As-produced product yields
- Product yields at standard cut points
- Product TBP cut points

**Yield Model**
- Yield offsets from model prediction

**Activity Model**
- Current catalyst activity for HDS, HDN, saturation, conversion

**Deactivation Model**
- Time localized deactivation rates for HDS, HDN, saturation, conversion
  - Tuned models

**Quality Model**
- Smoke point, cetane, viscosity index
- Directly analyzed or inferred product qualities, if not analyzed
- Updated quality models

**Equipment Design**
- Economically optimize manufacturing complex
  - Unit product rates
  - Unit product qualities
  - Provides operating responses for optimum

**Catalyst Limits**
- Practical constraints
  - Cycle length
  - Equipment limits
  - Catalytic limits

Leverages process expertise for attainable optima
Correlations are a basis for inference

- Cetane number indirectly related to higher boiling point through carbon number
- Cetane number indirectly related to specific gravity

Poly-A > Mono-A > Naphthenes > Paraffins

Source: NREL/SR-540-36805; September 2004

- AP = aniline point
- Txx = ASTM D86 T at xx% off
- D = density at 60° F
- V = viscosity at 104° F
- M%H = mass% H in an elemental analysis

Table 4  Fuel properties used by the seven best predictive equations

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<tr>
<th>Fuel property</th>
<th>3</th>
<th>16</th>
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<th>17</th>
<th>9</th>
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How can distillation be inferred?

- Product fractionators are common
  - Crude units
  - Conversion units
- Unique hydrocarbon partial pressure and compositions at product draws
- Changes in distillation measured only daily to weekly
- Basis for product qualities such as smoke point and cetane number or index
- Real-time optimization?
T* is a real-time parameter based on column operation
UOP-HPS Integrated Solutions for APC
Product Quality Inference – Distillate Fuels

Inferred ASTM T50%

- Commercial example demonstrates change in T50% can be predicted based on historical model of column or projected from latest updated laboratory data
- Neural network analysis indicates no significance of product specific gravities
- Methodology is applicable to product fractionators – for example, crude units, delayed coker, FCC, hydrocracking product fractionators

Process knowledge expertise leveraged
On-line sensors for combination of density, viscosity and temperature are common, inexpensive and reliable.

Install two at significantly different temperature locations to generate property temperature dependency.

Determine physical property values required for the quality correlation – i.e. cetane number or index.

Couple physical property values with inferred distillation to predict product property or change in product property based on latest laboratory measurements.

Use analyzers and process knowledge for property inference.
Profit Executive Components

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What-If steady state analysis using current operating conditions

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Dynamic operating plan moves provided to simulator

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APC Extensions
Bounds optimization problem based on APC constraints
Why not use an LP directly on line?

• Profit Executive (Super DQP) similarities to the LP:
  – They are both large scope optimizations
  – The modeling granularity is similar

• Differences
  – LP is not designed to run online
  – To be more effective the LP needs better information

• Key differentiators:
  – Profit Executive uses measured unit yields to account for mismatch
  – Profit Executive is closed loop utilizing yield models and feedback
  – Profit Executive is supplemented with real time constraint information from existing advanced control applications
    • Ensures a feasible solution and that feasible solution is implemented
Study Results to Date

• In the initial stages of prototyping and development

• Applicability
  – Distillate pool
  – Gasoline pool
  – Distribution/production scheduling
  – … a gap between the plan and the execution (e.g. gas distribution)

• Example: Profit Executive Benefit Study on Diesel production
  – The problem is easier to define because:
    ◆ Fewer significant inter-unit connections
    ◆ Fewer blending components and simple blending rules
    ◆ Fewer product specifications
A Refinery-wide Control Problem: JIT manufacturing

- The intermediate tanks here are for illustration and may vary from plant to plant.
Situation

• Varying demand (seasonal) for various grades of Diesel and Gasoline
• Front end limited
• Limited component tankage
  – Component tanks kept at higher property specifications to ensure no issues in blending the premium grades
  – Resulted in property giveaway on non-premium grades
• Daily corrections for plant limitations/logistics
  – Assumed plant was available to run at capacity

Mismatched operation can lead to imbalances in plant inventories

Assumed planning constraints for unit performance may be too aggressive or too conservative compared to actual performance
Study Results to Date (3)

• Results to date:
  – Once the FCC yield model and Gasoline pool constraints were added, the estimated Profit Executive benefits > US$1 per barrel of distillate*
    • Expect to capture 1/3 of giveaway
      • Cannot eliminate giveaway – function of schedule and available tankage

  – This result was obtained with:
    • All Profit Executive MV’s available
    • No optimization for units on days where operating problems are evident
    • No changes in the Diesel product delivery schedule which helps attain the third Profit Executive opportunity of coordinating the refinery operation to provide more of a ‘just in time’ production
    • No change to gasoline delivery schedule
    • No change to input crudes

* Based on crude pricing at the time of the study
Using real operating data, Honeywell determined that the refiner could save million of dollars from:

- Feed cost reduction – using cheaper crudes.
- Yield improvements – optimal routing
- Better tradeoff between distillate and napthas
- Reduce property giveaways
- Better coordination of production and blending
- Prolonging catalyst life and reduced hydrogen usage

Because the refinery was front end limited, only a very small benefit was attributed to increased crude throughput.
Next Steps

• Profit Executive Opportunity Assessment:
  – Review the modeling approach and the optimization approach, investigate several cases.
    ▪ Cases are generally optimizations that use different subsets of all the available MV’s
    ▪ Cases could also be set up for varying “safety margins” on final product qualities and quantifying the associated cost
  – Initial studies have been centered around the distillate pool, but could potentially expand the scope to include Gasoline production.

• Currently looking for early adopters to work with Honeywell to complete the development and productize Profit Executive
Assessment Inputs and Outputs

• **Opportunity Assessment:**
  – **Process review**
    - Process details, flows, current operation
    - APC status, scope
    - Planning process review, feed variation, yield model review
  – **Scope determination**
    - Potential process handles
    - Distillate pool, gasoline pool, overall scope
  – **Opportunity report**
    - Clarify scope and potential benefits based on the above work
    - Calendar time expectation of 3-5 months
  – **Expect time requirement from Planning, APC, Offsites**
Pursue Profit with Honeywell’s Profit Suite

- **Unified Technology**
  - Single platform from Experion-embedded to plant-wide control & optimization

- **Faster Realization of Benefits**
  - Designed for minimal effort to achieve the first dollar of benefits and build to larger benefits as ROI is justified

- **More Benefits Over Time**
  - The *most* comprehensive offering to transform business needs and objectives into real-time operations

- **Flexible Licensing**
  - Honeywell’s flexible approach to software licensing ensures maximum returns and protection of your investment
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