OPTIMIZE HYDROGEN NETWORK IN REFINERIES WITH RIGOROUS SIMULATION TOOLS

María J. Guerra, Manel Serra & Josep A. Feliu*
6th TRC-JCC / IDEMITSU International Symposium
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H₂ NETWORK OPERATIONAL OPTIMIZATION

➤ Introduction
➤ Solution Overview
➤ References
  ➤ Production optimization
  ➤ Consumers and purifiers optimization
➤ Conclusions
Independent Process Simulation Services Company

Established in Barcelona in late 2006 by four Process Simulation experts, nowadays employing more than 50 employees, with commercial offices in:

- Wiesbaden, Dubai, Houston, Mexico DF, Buenos Aires, Caracas, Rio Janeiro, Moscow

In any case, our mission has not changed:

- to help companies, which use process simulation, to get the whole of the value from their investment in software

INTRODUCING INPROCESS

- Technology Transfer / Training
  - Process Simulation Courses
  - Knowledge Improvement Program
  - Operations Training

- Process Simulation Projects
  - Steady State
  - Dynamics

- Lifecycle Projects / OTS
  - Dynamic Simulation Studies
  - DCS Check-out
  - Operator Training Systems

- Software Applications
  - PSA Simulator
  - H₂ Network Management Tool
  - Instructor Station
• Operating Companies
CLIENTS

- EPCs

[Image of various company logos]
CLIENTS

- Equipment Manufacturers and Instrumentation Providers

Honeywell
GE Oil & Gas
Atlas Copco
Emerson Process Management
MAN
Siemens
Yokogawa
Rockwell Automation
INTRODUCTION

- Hydrogen cost is becoming more significant due to increases in:
  - Demand (Sourer and heavier crudes, more Hydroprocessing capacity)
  - Price (Natural Gas price)
- Existing hydrogen networks should be operated in a way that:
  - Profitability of each process unit (hydroprocessing) is maximized
  - Hydroprocessing catalysts are not exposed to hydrogen partial pressures below operating limits
  - Is flexible enough to adapt to adjustments made in response to day-to-day changes in the refinery
  - The amount of hydrogen sent to fuel is minimized
INTRODUCTION

• A H$_2$ network on-line advisory tool, that can propose optimal operating conditions, would help to achieve such objectives

• It requires:
  – Connectivity application to handle communication with real plant on line data
  – Interface with continuous operational recommendations
  – A detailed simulation model of the existing network connectivity and involved units
  – Calibration and optimization every 15 min
  – Interface for what-if studies
SOLUTION OVERVIEW

• Configuration

Execution frequency can be modified by the application user.
SOLUTION OVERVIEW

• Phases of a H₂ Network Optimization Project
• Phases of a H₂ Network Optimization Project
SUCCESS STORY 1: CEPSA’S GIBRALTAR-SAN ROQUE REFINERY

- Hydrogen Network Schematic
**SUCCESS STORY 1: CEPSA’S GIBRALTAR-SAN ROQUE REFINERY**

- **Challenges:**
  - Collect and reconcile \( \text{H}_2 \) network related plant information
  - Minimize cost of hydrogen
    - Minimize \( \text{H}_2 \) plant load
    - Minimize Reformer#2 Load (if product price scenario allows it)
    - Minimizing all purges to fuel gas
    - Maximize recovery in PSA unit
  - Crude changes and capacity changes
  - Plan unit shut down
SUCCESS STORY 1: TECHNICAL SOLUTION

- Aspen HYSYS Simulation model of the H₂ network
SUCCESS STORY 1: TECHNICAL SOLUTION

• Aspen HYSYS Simulation model of the H₂ network
SUCCESS STORY 1: TECHNICAL SOLUTION

- Aspen HYSYS Simulation model of the H₂ network
SUCCESS STORY 1: TECHNICAL SOLUTION

• Hydroprocessing unit models

• Specific simulation model for every unit
  – Calibration and Simulation within the same model
  – Monitoring of hydrogen consumption
SUCCESS STORY 1 – TECHNICAL SOLUTION, PSA SIMULATION

- Pressure Swing Adsorption Unit was a key element in the network operation
- Unit operates on a cyclic basis: combination of multiple adsorption beds that provide constant product and off gas flows
- Adsorbents are able to retain more impurities at high pressure than low pressure. Pressure swings to regenerate beds
SUCCESS STORY 1 – TECHNICAL SOLUTION, PSA SIMULATION

• Dynamic model of the PSA unit
  – Solves, for time and bed length, differential conservation equations for mass, heat and momentum along with Langmuir equilibrium equations developed by a University
  – Literature values for adsorbent properties
  – Fits experimental data well

• Allows rigorous evaluation of operating parameters
  – Cycle time
  – Feed flowrate
  – Feed composition
SUCCESS STORY 1 – TECHNICAL SOLUTION, PSA SIMULATION

- Possible operating envelope for the optimizer
  - Maximizing Recovery
  - Maximum feed flowrate, depending on feed purity
SUCCESS STORY 1: TECHNICAL SOLUTION

• Optimization
  – Process Variables:
    • $\text{H}_2$ plant load (Including shutdown)
    • Reformer #2 Load
    • Makeup flow of main hydrotreaters
    • PSA Purification unit load
  – Constraints:
    • Hydrotreater recycle purity for each unit
  – Objective function
    • Hydrogen cost when plant production allow it
    • Increased hydrotreater purities when not
SUCCESS STORY 1: USER INTERFACE

- User Interface shows current network configuration
SUCCESS STORY 1: USER INTERFACE

- It collects from plant data current H₂ productions, Hydrotreater make-up, purges, purities and other variables
SUCCESS STORY 1: USER INTERFACE

- It calculates material imbalances, network purities, H₂ consumption and other unit variables
SUCCESS STORY 1: USER INTERFACE

- After Calibration step, optimization is run
- Manipulated variables, constraints and objective function
- Treats results to give optimized operating suggestions
SUCCESS STORY 1: BENEFITS

- Benefits study

<table>
<thead>
<tr>
<th>Study Case</th>
<th>Average Daily Cost Reduction (€/day)</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3290</td>
<td>Reduce platforming load</td>
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<tr>
<td>II</td>
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<td>H2 excess – increased catalyst life</td>
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<td>III</td>
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</tr>
<tr>
<td>V</td>
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<td>H2 excess – increased catalyst life</td>
</tr>
</tbody>
</table>

H2 Price 1400 €/tonne

- If on-line, the optimizer results must not show large benefits (otherwise, it would not have been useful)
SUCCESS STORY 2: REPSOL – PUERTOLLANO REFINERY

- Hydrogen Network Schematic
SUCCESS STORY 2: REPSOL – PUERTOLLANO REFINERY

• Challenges:
  – Collect and reconcile H₂ network related plant information
  – Minimize cost of hydrogen
    • Minimizing purges to fuel gas
    • Use lowest cost hydrogen, based on source and operating capacity
  – Evaluate imbalances in order to improve instrumentation
  – Evaluate operating scenarios
SUCCESS STORY 2: TECHNICAL SOLUTION

• Aspen HYSYS Simulation model of the H₂ network
SUCCESS STORY 2: TECHNICAL SOLUTION

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SUCCESS STORY 2: TECHNICAL SOLUTION

- Aspen HYSYS Simulation model of the H₂ network
SUCCESS STORY 2: TECHNICAL SOLUTION

• Hydroprocessing unit models
  – Specific simulation model for each unit
    • Calibration and Simulation within the same model
    • Calculate reactor parameters by balance
    • Simulation reproduces $H_2$ separation
SUCCESS STORY 2: TECHNICAL SOLUTION

• Optimization
  – Process Variables:
    • Hydrogen production for the two units
    • Feed charge to hydrotreaters - on demand
  – Constraints:
    • Hydrotreaters recycle purity constraint
    • Additional one compressor constraint
  – Objective function
    • Price structure based on load
    • Allows for monthly update
SUCCESS STORY 2: BENEFITS

• Benefits Study
  – Select the optimal H₂ source based on operating plant load
  – Minimize H₂ purges to FG

<table>
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<tr>
<th>Study Case</th>
<th>Peak Cost Reduction (€/hour)</th>
<th>Average Daily Cost Reduction (€/day)</th>
</tr>
</thead>
<tbody>
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<td>V</td>
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<td>3721</td>
</tr>
</tbody>
</table>

– If on-line, the optimizer results must not show large benefits (otherwise, it would not have been useful)
CONCLUSIONS

• Inprocess’ H₂ Network Management Tool allows for the online optimization of a refinery hydrogen production/consumption
• Savings are achievable
• Due to the availability of a calibrated rigorous network model, connected online with Plant Instrumentation Database, additional benefits can be obtained:
  – Improvement of online monitoring instrumentation
  – Monitoring chemical hydrogen consumption,
  – Other refinery operating parameters
THANK YOU!

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Josep Anton accumulates 25 years of experience in Process Modeling and Simulation for systems ranging from biological ones to oil & gas, refining, petrochemicals and polymers. Having taught at Universitat Autònoma de Barcelona, he joined Hyprotech as the EMEA Regional Manager for Customer Support and Training, position where he remained after Aspentech acquisition. In that role, Josep Anton helped clients, participated in modelling projects and enhanced the existing training material. Taking advantage of his lecturing experience, he did also teach countless Process Simulation courses.

Josep Anton, at Inprocess, now manages the Marketing and Proposals Department, after having lead the Training Department since its inception, thus being responsible for the development and deployment of all Inprocess’ clients educational requirements.