FCCU Advanced Control at Chevron Pembroke Refinery

ERTC
8th to 10th May 2006
Yen Koo CVX
Zak Friedman Petrocontrol
Steve Park AMT
FCC at Pembroke Refinery

- Initial Hydro skim refinery commissioned in 1967
- Cracking facilities commissioned in 1983 (Texaco side by side Rx/Rg unit, with a main fractionator and gas concentration section)
- Can process over 35% resid of total throughput of over 100,000 BPSD (600m3/hr - One of the Biggest FCC in Europe)
- Feed mix variation is in the region of 0.908 to 0.92 SG
- Last major turn around is during 2003
History of APC at Pembroke

- Pembroke Refinery has a long history of APC since 1987
- First MVC controller on FCC – 1988 (DMC) – with separate controller for Rx/Rg, and Mainfrac
- 2001, RMPCT replaced DMC, retained original structure, and added deeth, debut, napsplit
- Very limited success at each time (mainfrac didn’t work, lack of co-ordination between applications, tray damage)
- First Principle Inferentials first used in early 1990’s and have been deployed across most refinery units
FCCU APC Reengineering

- Potentially US$ 4 millions/yr yet to be captured (carried a study on FCC APC during 2004) - Need to completely revamp FCC APC
- Scope of the revamp to cover reactor, regenerator, mainfrac, deeth, debut
- Main focus of the application and this paper is the Fractionator section due to major difficulties in managing this section of the unit
- Major feed limiting constraints are mainly in the Fractionator section
- RMPCT is the control technology used
- New FCCU application commissioned in July 2005
Operating within Constraints

True Economic optimum

Max Tot. feed, Max Resid, ROT
Max prod: LCGO (up-grade more HCGO)
Max HHCN (match ULSG Capacity)
Max Ole (match Alky Capacity)
Min usage Air, Min C3 loss to offgas

WGC Anti-surge
Airblower anti-surge
HP steam limitation

Rx/Rg Temperature
Eg. Rx bed Temp.
Rg flu gas Temp.
Excess O2,
Cyclone Vel

System Pressure
Eg. Rx/Rg DP.
Mainfrac top P
SCSV/RCSV – DP
And OP
Mainfrac OVHD P

Hydraulic Const.
Eg. Control valve
Saturation OP – reflux & cooling system

Column fouling/ flooding limitation
LCGO draw TY DP, Level,
Glitsch grid flow,
TPA DP, ICGO wash down
Mainfrac bottom Temp.

MVC Operating Region
WGC & others

Operator’s Preferred Operating Region

Product Purity
HCN90 & EP
HHCN90 & EP
LCGO Flash
Slurry Density
C2 spec in Ole

Petrocontrol
FCCU application overview

- Applications are as follows:
  - Rx, Rg/mainFrac/Deeth (better integration and optimisation) – 55CVs, 22MVs, 11DVs
  - Single application to cover Debutaniser (8CVs, 4MVs, 6DVs)
- Large scope application with sub controllers deployed for ease of maintenance and operator intervention. *(Sub controller switch AM/CL code supplied by AMT)*
- Customised Operator displays developed by CVX and AMT
  - Easy monitoring and operated upon (by panel operators)
  - Accommodation for switching access
- First principle Inferential model based on GCC (Petrocontrol)
Overview of Revamp Design

FCCU Block Flow Diagram

- Waste Heat Boiler
- PRT & Flue Gas
- Main Frac Overheads
- Wet Gas Compressor
- Prosat Naph Abs Sponge Abs
- Amine Scrubber
- Reboil capacity from LCGO PA / Reflux
- ICGO PA / Reflux
- HCGO PA / Reflux

Typical Constraints
- Typical prod. & spec.

Typical Constraints
- RMPCT Application
- WGC Anti-surge
- HP STM limitation
- C2 spec in Ole
- C5 in Ole prod.
- DP & OP Mainfrac OVHD P
- SCSV/RCSV – DP And OP Mainfrac OVHD P
- Eg. Rx/Rg DP, Mainfrac top P
- Excess O2, Cyclone Vel
- Glitsch grid flow, TPA DP
- ICGO wash down MF BTM T.
- Cooling duty
- HCN90 & EP
- HCNO90 & EP
- HHN90 & EP
- LCGO Flash
- HCGO
- HCGO Prod
- HCGO Density
- Olefin Merox
- ULSS
- Downstream units limitation

C5 in Ole

- HP Sour Depth

Reboil capacity from LCGO PA / Reflux

- Naptha Splitter

- Stack
- Primary
- Secondary
- PRT MTR-GEN POWER

- HP Steam
- Cooling Capacity
- SWS
- HP Sour Depth

- Airblower anti-surge
- Cold VGO
- Hot LGO
- Hot ATM
- Cold ATM

- Reactor / Regenerator
- Eg. Rx/Rg DP
- Eg. Rx bed T
- Rg flu gas T.
- Excess O2, Cyclone Vel

- Feed Heaters

- Downstream units limitation

- Petrocontrol

- AMT
Schematic of Main fractionator

Reactant Effluent

Cold Feed

TPA

LCGO PA

ICGO PA

Min Tray Wash

Min Grid Flow

Max btm temp

Max yield on resid feed

Max to min traywash

Flash point spec

90% Dist

Lean Oil to Absorber

Wet Gas

90% Dist

HHCN Product

Lean Oil to Absorber

Min Grid Flow

Max yield on resid feed

Max velocities

Max btm temp

90% Dist

LCGO Product

Flood limit

Temp min "dew point"

Petrocontrol
Project details Schedule and contract

- Project was completed in a 8 month window.
- Inferential model provided by Petrocontrol, and implemented and subsequent re-calibrated by CVX (VBA-model for easy maintaining and calibration)
- APC model jointly developed and implemented by CVX and AMT (one engineer each)
- Operator training package jointly developed by CVX and AMT (computer based self-learning, interactive)
- Project completed under budget with benefits higher than expected
FCCU APC Application Success Factors

- New FCCU application commissioned in mid-June 2005
- High operator acceptance
- Good average controller uptime (>95% when process available)
- Fractionator control now much improved, this is a key issue for the FCCU unit operations.
- Payback achieved within a month
Feature – inferentials/Specs Control

• Fractionator:
  – LCGO Flash Point
  – HHCN ASTM 90% & End point
  – HCN ASTM 90% & End point

• Gas Plant
  – Deeth bottom % C2 slippage
  – Olefin % C5
  – LCN RVP

• Note: no analyser or lab updates used for biasing inferences
Highlight - Inferential models
## Sample Model – Spec Control

<table>
<thead>
<tr>
<th>MF Top-T</th>
<th>MF OVHD-T</th>
<th>LCGO prod.</th>
<th>HCGO PA</th>
<th>LCGO RBL</th>
<th>Deeth RBL</th>
<th>Ambient-T</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
<td><img src="image7" alt="Graph" /></td>
</tr>
<tr>
<td><img src="image8" alt="Graph" /></td>
<td><img src="image9" alt="Graph" /></td>
<td><img src="image10" alt="Graph" /></td>
<td><img src="image11" alt="Graph" /></td>
<td><img src="image12" alt="Graph" /></td>
<td><img src="image13" alt="Graph" /></td>
<td><img src="image14" alt="Graph" /></td>
</tr>
<tr>
<td><img src="image15" alt="Graph" /></td>
<td><img src="image16" alt="Graph" /></td>
<td><img src="image17" alt="Graph" /></td>
<td><img src="image18" alt="Graph" /></td>
<td><img src="image19" alt="Graph" /></td>
<td><img src="image20" alt="Graph" /></td>
<td><img src="image21" alt="Graph" /></td>
</tr>
<tr>
<td><img src="image22" alt="Graph" /></td>
<td><img src="image23" alt="Graph" /></td>
<td><img src="image24" alt="Graph" /></td>
<td><img src="image25" alt="Graph" /></td>
<td><img src="image26" alt="Graph" /></td>
<td><img src="image27" alt="Graph" /></td>
<td><img src="image28" alt="Graph" /></td>
</tr>
</tbody>
</table>
Highlight - LCGO Flash Point control

Infer LCGO FP
Lab LCGO FP
Infer LCGO FP Sdev

Inferential recalibrated & new controller

Average Standard deviation is reduced by 1DegC
Highlight – HCN90 spec control

Average Standard deviation is reduced by 1DegC
Feature – mainfrac control

- Optimise where possible the Fract bottoms heat removal
  Control Fractionator bottom temperature
- Prevent Fractionator flooding
- Maximise heat removal and balance duty around the column
- Ensure column packed sections are kept wet
- Ensure Slurry oil density remain on control within tight limits
- Minimise fouling probabilities in Slurry system
- Sustains Debutaniser on control even though reboiler (HCGO) exchanger fouling occurs
## Sample Model – Main Frac control

<table>
<thead>
<tr>
<th>Feed</th>
<th>ROT</th>
<th>MF Top-T</th>
<th>LCGO prod.</th>
<th>HCGO PA</th>
<th>ICGO PA</th>
<th>HHCN prod</th>
</tr>
</thead>
<tbody>
<tr>
<td>MainFrac</td>
<td>Bottom Temp.</td>
<td>Packed Section</td>
<td>ICGO Wash</td>
<td>LCGO Draw LVL</td>
<td>LCGO Draw DP</td>
<td>HCGO Visc</td>
</tr>
<tr>
<td><img src="image1.png" alt="Graph1" /></td>
<td><img src="image2.png" alt="Graph2" /></td>
<td><img src="image3.png" alt="Graph3" /></td>
<td><img src="image4.png" alt="Graph4" /></td>
<td><img src="image5.png" alt="Graph5" /></td>
<td><img src="image6.png" alt="Graph6" /></td>
<td><img src="image7.png" alt="Graph7" /></td>
</tr>
<tr>
<td><img src="image9.png" alt="Graph9" /></td>
<td><img src="image10.png" alt="Graph10" /></td>
<td><img src="image11.png" alt="Graph11" /></td>
<td><img src="image12.png" alt="Graph12" /></td>
<td><img src="image13.png" alt="Graph13" /></td>
<td><img src="image14.png" alt="Graph14" /></td>
<td><img src="image15.png" alt="Graph15" /></td>
</tr>
<tr>
<td><img src="image17.png" alt="Graph17" /></td>
<td><img src="image18.png" alt="Graph18" /></td>
<td><img src="image19.png" alt="Graph19" /></td>
<td><img src="image20.png" alt="Graph20" /></td>
<td><img src="image21.png" alt="Graph21" /></td>
<td><img src="image22.png" alt="Graph22" /></td>
<td><img src="image23.png" alt="Graph23" /></td>
</tr>
<tr>
<td><img src="image25.png" alt="Graph25" /></td>
<td><img src="image26.png" alt="Graph26" /></td>
<td><img src="image27.png" alt="Graph27" /></td>
<td><img src="image28.png" alt="Graph28" /></td>
<td><img src="image29.png" alt="Graph29" /></td>
<td><img src="image30.png" alt="Graph30" /></td>
<td><img src="image31.png" alt="Graph31" /></td>
</tr>
<tr>
<td><img src="image33.png" alt="Graph33" /></td>
<td><img src="image34.png" alt="Graph34" /></td>
<td><img src="image35.png" alt="Graph35" /></td>
<td><img src="image36.png" alt="Graph36" /></td>
<td><img src="image37.png" alt="Graph37" /></td>
<td><img src="image38.png" alt="Graph38" /></td>
<td><img src="image39.png" alt="Graph39" /></td>
</tr>
<tr>
<td><img src="image41.png" alt="Graph41" /></td>
<td><img src="image42.png" alt="Graph42" /></td>
<td><img src="image43.png" alt="Graph43" /></td>
<td><img src="image44.png" alt="Graph44" /></td>
<td><img src="image45.png" alt="Graph45" /></td>
<td><img src="image46.png" alt="Graph46" /></td>
<td><img src="image47.png" alt="Graph47" /></td>
</tr>
<tr>
<td><img src="image49.png" alt="Graph49" /></td>
<td><img src="image50.png" alt="Graph50" /></td>
<td><img src="image51.png" alt="Graph51" /></td>
<td><img src="image52.png" alt="Graph52" /></td>
<td><img src="image53.png" alt="Graph53" /></td>
<td><img src="image54.png" alt="Graph54" /></td>
<td><img src="image55.png" alt="Graph55" /></td>
</tr>
</tbody>
</table>
Highlight - LCGO Section dP Sensitivity to Flood

LCGO Section dP

Controller commissioned

Flood point

Unit being pushed and stability retained

Chevron

Petrocontrol
Highlight - Fractionator BTM T Critical Unit limitation

Fractionator bottom temperature

355°C is High Operating Limit

Controller Commissioned

Bottom Temp
Stdev
Feature – Optimisation direction

- Maximise Total Feed (match scheduling)
- Max Resid processing to Regen limitations
- Minimise load on Blower and expander
- Stay in safe system delta P range (slide valves) – max cat circulation
- Maximise Conversion
- Run to minimum Regen excess O2 (>1%)
- Max LCGO draw against MIN internal reflux
  - Significant operator issue
- Minimises the Deethaniser C3’s loss to offgas subject to C2 content at bottom (ole prod)
## Sample Model – Rx/Rg optimisation

<table>
<thead>
<tr>
<th>Tot-Feed</th>
<th>Reactor-Temp</th>
<th>Resid-Feed</th>
<th>Rx/Rg-DP</th>
<th>Feed-Preheat</th>
<th>MF Top-P</th>
<th>Air-blower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess O2</td>
<td>RCSV DP</td>
<td>RCSV OP</td>
<td>Airblow</td>
<td>Anti-srg</td>
<td>WGC</td>
<td>Anti-srg</td>
</tr>
<tr>
<td>Rx bed Temp</td>
<td>Cat. Circ.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Unit Feed and Yields in M3/HR
Shows increase in recovery of LCGO whilst sustaining bottom conditions

Feed rate conditions dictated by refinery and plant issues, Application ran at >95% from start of application

Increased recovery of LCGO at expense of internal reflux (traywash) and hence Slurry yield - Gain of 1
Highlight – Excess O2 optimisation

Excess O2 regen flu gas

Controller
Commissioned

Unit is pushed to the limit
Feature – operator Acceptance

- Easy & user friendly APC monitoring display
- Comprehensive operator’s training
### Highlight – Customised Operator Display

<table>
<thead>
<tr>
<th>MV DESC.</th>
<th>MV VALUE</th>
<th>MV MOVE</th>
<th>LOLIM</th>
<th>HILIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC1967 PRIM</td>
<td>117.0</td>
<td>122.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC075 MF/TO</td>
<td>131.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC2612 LCGO</td>
<td>10.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC2368 CHIL</td>
<td>55.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC2369 CHIL</td>
<td>40.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC1926 ICGO</td>
<td>450.0</td>
<td>460.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC044 HCGO</td>
<td>-0.04</td>
<td>380.0</td>
<td>410.0</td>
<td></td>
</tr>
<tr>
<td>FC067 HCGO</td>
<td>0.01</td>
<td>430.0</td>
<td>495.0</td>
<td></td>
</tr>
<tr>
<td>FC2175 HCGO</td>
<td>-0.68</td>
<td>190.0</td>
<td>220.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CV DESC.</th>
<th>CV VALUE</th>
<th>SSVAL</th>
<th>LOLIM</th>
<th>HILIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF HCN90</td>
<td>177.9</td>
<td>188.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF HCN EP</td>
<td>194.6</td>
<td>190.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF HHCN90</td>
<td>215.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF HHCN EP</td>
<td>230.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF LCGO FLS</td>
<td>81.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLITSC FLO</td>
<td>100.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC035 SP IC</td>
<td>129.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCGO VISCO</td>
<td>16.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCG0 DENSIT</td>
<td>109.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LR3208 TY18</td>
<td>90.51</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FR1980 TPA</td>
<td>322.3</td>
<td></td>
<td>220.0</td>
<td>370.0</td>
</tr>
<tr>
<td>FC2368/9DIF</td>
<td>75.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PD3056 LCGO</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC060 HCGO</td>
<td>41.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC075 OP</td>
<td>17.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC1967 OP</td>
<td>58.33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC2612 OP</td>
<td>14.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC1926 OP</td>
<td>61.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC2368 OP T</td>
<td>26.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC2369 OP T</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Able to switch on/off the whole controller
- Able to switch on/off, between Sub-controller
- Able to drop any CVs or MVs
- Able to see which are the critical variables
- Able to change Low/High Limit
Overview – How to navigate through the Training

Each CV and MV is presented by a set of 3 standard slides:

1. DCS Ops display: click Here-1 to see live DCS screen shot. Normally Ops performs actions such as turn on/off RMPCT, change Hi/Lo limit of CV or MV, drop off CV or MV on this display. Click Here-2 to see more.

2. Process Schematic: click Here-3 to see FCC process flow diagram with CV and MV labels. Click Here-4 to see more.

3. RMPCT Move Strategy Matrix: click Here-5 to see typical MV’s move when at CV constraint. Click Here-6 to see more.

At top right corner of every slide, there are 6 navigating buttons to aid user to navigating through out this presentation.

On every slide, click ↓ to show / hide more control information for the CV or MV in discussion, click ↑ to see the related DCS Ops Display, click ← to view the related RMPCT Move Strategy Matrix, click → to return to the CV or MV in discussion, click → to advance to next slide. If not to how to navigate through, click ↑ to view this HELP slide.

At any time to exit from the training, press the Esc key on the keyboard. Ready to start..... then click Here-8 to begin the tutorial.
Thank you

Questions