Implementation of APC in Prime–G+

Indian Oil Corporation Limited
Mathura Refinery
Topic Involves

- What is Prime−G⁺
- Prime−G⁺ Process & APC from Licensor’s perspective
- APC in IOCL Prime−G⁺
- APC scheme
- Model and Control Concept
- APC Performance
- APC Benefit in Prime−G⁺
- APC Inferential Properties
What is Prime-G+?

- FCC GASOLINE **Selective Desulfurization**.
- Very high desulfurization rate with **good octane retention**
- Gasoline yield retention **without RVP increase** (no cracking reactions)
- High catalyst cycle length that keeps the unit running 100% of the FCC turnaround
- Ability to co-process other sulfur-rich streams such as light Coker, visbreaker, straight run or steam cracker naphtha
Prime-G+ Licensor’s (‘Axens’) APC Concept
Prime-G+ IOCL APC Concept

Operated by different control room & DCS (difficulty in operation).
- So Prime-G APC can’t be extended

Executed by M/s Yokogawa India Limited using EXASMOC and EXARQE software
Objective-SHU:

- Reject feed disturbances and maintain level: Feed forward method
- Maintain SHU RIT: Feed forward method
**Objective-HDS:**
- Reject feed disturbances and maintain RIT : Feed forward method
- Reject disturbance due to varying extent of exothermic reaction and maintain RIT : Feed forward method
- Minimize Fuel gas and Maximize Stabilizer Btm ‘S’ : Optimization
Objective-HDS:
• Maximization of ‘S’ happens by reducing fuel gas and as a result, the RIT.
• Reduction of RIT reduces the extent of both – Hydro-desulfurization and olefin saturation reactions
• Hence, both Maximization of ‘S’ and Reduction in RON loss is obtained
• ‘Stabilizer Bottom-S’ gives the indication of HDS exit ‘S’
**Objective-Stabilizer:**

- Reject flow disturbances from GSU and maintain ‘Bottom Temp’ (192-194 C) : Feed forward method
Objective-Stabilizer:

- Minimize steam

: Optimization
## APC Performance: On-line Factor

<table>
<thead>
<tr>
<th>S. No</th>
<th>DESCRIPTION</th>
<th>Total SAT hrs excluding Process Disturbance</th>
<th>Total APC online Hours excluding Process Disturbance</th>
<th>APC On-stream Factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PRIMEG CONTROLLER</td>
<td>360.00</td>
<td>358.26</td>
<td>99.51</td>
</tr>
<tr>
<td>2</td>
<td>SHUCON SUBCONTROLLER</td>
<td>360.00</td>
<td>358.26</td>
<td>99.51</td>
</tr>
<tr>
<td>3</td>
<td>MV – 306FIC0101.SP</td>
<td>360.00</td>
<td>357.78</td>
<td>99.38</td>
</tr>
<tr>
<td>4</td>
<td>MV – 306FIC0202.SP</td>
<td>360.00</td>
<td>358.21</td>
<td>99.50</td>
</tr>
<tr>
<td>5</td>
<td>MV – 306FIC0203.SP</td>
<td>360.00</td>
<td>358.26</td>
<td>99.50</td>
</tr>
<tr>
<td>6</td>
<td>HDSCON SUBCONTROLLER</td>
<td>360.00</td>
<td>356.73</td>
<td>99.00</td>
</tr>
<tr>
<td>7</td>
<td>MV -307FIC0684.SP</td>
<td>360.00</td>
<td>356.12</td>
<td>98.92</td>
</tr>
<tr>
<td>8</td>
<td>MV -307FIC0605.SP</td>
<td>360.00</td>
<td>354.87</td>
<td>98.57</td>
</tr>
<tr>
<td>9</td>
<td>MV -307PIC1003.SP</td>
<td>360.00</td>
<td>356.66</td>
<td>99.00</td>
</tr>
</tbody>
</table>
APC Performance: Standard Deviation (1/3)

Standard deviation Reduction in SHURIT – 306_TIC_0270.PV

<table>
<thead>
<tr>
<th>SHURIT</th>
<th>Standard deviation Before APC</th>
<th>Standard deviation After APC</th>
</tr>
</thead>
<tbody>
<tr>
<td>306_TIC_0270.PV</td>
<td>0.53</td>
<td>0.23</td>
</tr>
</tbody>
</table>
## APC Performance: Standard Deviation (2/3)

<table>
<thead>
<tr>
<th></th>
<th>Standard deviation Before APC</th>
<th>Standard deviation After APC</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDS RIT-1 _TI_0642.PV</td>
<td>8.0</td>
<td>4.5</td>
</tr>
<tr>
<td>HDS RIT-2 _TIC_0635.PV</td>
<td>7.2</td>
<td>4.8</td>
</tr>
</tbody>
</table>
APC Performance: Standard Deviation (3/3)

<table>
<thead>
<tr>
<th></th>
<th>Standard deviation Before APC</th>
<th>Standard deviation After APC</th>
</tr>
</thead>
<tbody>
<tr>
<td>307_TL_0607.PV</td>
<td>10.13</td>
<td>4.78</td>
</tr>
</tbody>
</table>
### APC Benefit: Reduction of RON Loss

<table>
<thead>
<tr>
<th></th>
<th>Rundown Sulphur</th>
<th>RON Loss</th>
<th>Prime-G FD Sulphur - (1)</th>
<th>Feed Sulphur/Rundown Sulphur - (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE APC</td>
<td>83.94</td>
<td>$=90.73-89.91 = 0.82$</td>
<td>314</td>
<td>3.79</td>
</tr>
<tr>
<td>SAT</td>
<td>94.72</td>
<td>$= 91.34 - 90.83 = 0.52$</td>
<td>239</td>
<td>2.59</td>
</tr>
<tr>
<td>Improvement</td>
<td>11.0</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- So Improvement should be NORMALIZED, as Parameter-1 & 2 BEFORE APC & SAT are not same
- Base-case RON Loss is normalized by REGRESSION analysis w.r.t parameter-(1) & (2)
- Normalized Base-case RON Loss = 0.63
- Normalized RON Improvement = $0.63 - 0.52 = 0.114$ (projected Target = 0.067)
## Benefit due to RON Improvement

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RON Improvement from the Rundown stream (MS) of Prime-G+ Unit after MVPC Implementation</td>
<td>0.114</td>
</tr>
<tr>
<td>1 Unit of RON Improvement corresponds to 1 MT of Motor Sprit (MS) Processed</td>
<td>Rs. 91.30</td>
</tr>
<tr>
<td>Annual Processing of Feed (MS) in Prime-G+ Unit (Not considering the Heart cut drawn from FCCU-GSU)</td>
<td>3,76,487.00 MT</td>
</tr>
<tr>
<td>Estimated Annual Benefit due to MVPC application in Prime-G+ Unit</td>
<td>Rs. 39,18,551</td>
</tr>
<tr>
<td>≈Rs.39.19 Lakhs</td>
<td></td>
</tr>
</tbody>
</table>
# APC Benefit: Stabilizer Bottom Steam Minimization

<table>
<thead>
<tr>
<th></th>
<th>Average Steam flow (Kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE APC</td>
<td>3387.20</td>
</tr>
<tr>
<td>SAT</td>
<td>3288.72</td>
</tr>
<tr>
<td>Improvement</td>
<td>98.48</td>
</tr>
</tbody>
</table>

- **Steam Saving for 330 days/annum of operation**

  \[
  = 98.48 \times 8000 \times 1600 \text{ Rs/Annum} \\
  \quad (\text{Assumption : Steam Price 1600 Rs/MT})
  \]

  \[
  = \text{Rs. } 12.6 \text{ Lakhs}
  \]
APC Benefit : Total Prime-G+

Total Benefits in Prime-G+ due to APC

Benefit due to RON Improvement = Rs.39.19 Lakhs/annum
Steam Minimization Benefits at Stabilizer Section = Rs.12.6 Lakhs/annum

Total Benefits in Prime-G+ due to APC = Rs. 51.8 Lakhs/annum

(Target Benefit = 24 Lakhs/annum)
Stabilizer Bottom Sulphur (RQE-3)

<table>
<thead>
<tr>
<th>Tag Name</th>
<th>Tag Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDSFD_SULPHUR.PV</td>
<td>HCN Sulphur (HDS Feed Sulphur RQE-2 Estimation)</td>
</tr>
<tr>
<td>307TI0642.PV</td>
<td>HDS Reactor 1\textsuperscript{st} bed Inlet Temperature</td>
</tr>
<tr>
<td>307TI0630.PV</td>
<td>HDS Reactor 2\textsuperscript{nd} bed Bottom Temperature</td>
</tr>
<tr>
<td>307TI1014.PV</td>
<td>Stabilizer Bottom Temperature</td>
</tr>
</tbody>
</table>

- RQE-3 depends on \textit{“HDS input S”} (RQE-2) and \textit{Prime-G Hot Feed Sulphur} (RQE-1).
- \textit{“HDS input S”} is calculated based on AVU, FCC feed & it’s dynamics & GSU dynamics & disturbances.
- So: \( RQE-3 = f \left( RQE-2 \right) \); \( RQE-2 = f \left( RQE-1 \right) \)
**APC Inferential**

**HDS Feed Sulphur (RQE-2)**

<table>
<thead>
<tr>
<th>Tag Name</th>
<th>Tag Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSUFD_SULPH</td>
<td>Feed to FCCGSU (calculation)</td>
</tr>
<tr>
<td>20PI0802.PV</td>
<td>FCCGSU Top Pressure</td>
</tr>
<tr>
<td>20FC0306.PV</td>
<td>FCCGSU Light Cut Draw Flow</td>
</tr>
<tr>
<td>20FC0404.PV</td>
<td>FCCGSU Heart Cut Draw Flow</td>
</tr>
</tbody>
</table>

**FCCU feed Sulpher is mixer of following=>**

<table>
<thead>
<tr>
<th>Flow Stream</th>
<th>Density</th>
<th>Sulphur Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OHCU Bottom from tank (M3/HR)</td>
<td>0.875</td>
<td>100</td>
</tr>
<tr>
<td>LS VGO from tank (M3/HR)</td>
<td>0.9</td>
<td>6000</td>
</tr>
<tr>
<td>BH VGO from tank (M3/HR)</td>
<td>0.9</td>
<td>4000</td>
</tr>
<tr>
<td>OHCU Bottom hot feed (M3/HR)</td>
<td>0.875</td>
<td>100</td>
</tr>
<tr>
<td>HOT feed from AVU (M3/HR)</td>
<td>0.9</td>
<td>BH -1: 4000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HS – 2: 30000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nigerian – 3: 6000</td>
</tr>
<tr>
<td>DHDS VGO flow (KG/HR)</td>
<td></td>
<td>2000</td>
</tr>
</tbody>
</table>

**Prime-G Feed Sulphur (RQE-1)**

<table>
<thead>
<tr>
<th>Tag Name</th>
<th>Tag Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCCUFD_SULPH</td>
<td>Sulphur at FCCU (calculation)</td>
</tr>
<tr>
<td>19TRC153.PV</td>
<td>Main Fractionator Top Temperature</td>
</tr>
<tr>
<td>20TI99.PV</td>
<td>Debutanizer bottom temperature</td>
</tr>
</tbody>
</table>

**Tag Name**

**Tag Description**

- Sulphur at FCCU (calculation)
- Main Fractionator Top Temperature
- Debutanizer bottom temperature
Stabilizer ‘Btm S’ is a small PPM number, so effect of input parameter is very SENSITIVE

Direct measurement of HDS input S is very important for accuracy.

Assumption error is getting lumped and accumulated at RQE-3 !!!!

So present RQE predictions are best with the given assumptions.

Recommends frequent updation based on Lab or Online measurement.
Stab btm S – APC Inferential vs LAB (on Overall basis)
Stab btm S – APC Inferential vs LAB (on daily basis)

First Update after Holiday & Wrong Sampling point misguided the updation

Feed ‘S’ change & Update Mismatch (effect of Sulphur lag in the process eliminated by updating with different Sulphur values)

First Update after Holiday
Stabilizer bottom Sulphur prediction vs Analyzer @ 1d0h0m0s
Stab btm S – Maximization

Stab bottom S maintained at its high limit @ 1d0h0m0s
Thank You!
APC Models

**Example:**
1. Flow, Temperature, Pressure
2. Furnace COT

**Example:**
1. SHU drum Level
2. Temperature of Run away Reaction (ROT-2) (Reactor outlet temperatures)

PLUS in this process

If ROT-2 is ramp then RIT1 ramp
Efforts made to smoothen HDS feed rate fluctuations: PID-Tuning, Averaging RITs, making DCS calculations

All Effort to smoothen the HDS feed rate change failed

1\textsuperscript{st} Order model of RIT-1 is changed to 1\textsuperscript{st} order-ramp:

- RIT-1 stabilization needs disturbance rejection.
- RIT-1 = f (HDS feed & ROT) & ROT = f (RIT-1)
  
Where: ROT is ramp variable.

- Therefore RIT-1 changed to Ramp variable.

RIT-1 changed to instantaneous measurement.

RIT(AUT) as CV & Fuel gas as MV is considered to catch anti-wind-up facility of fuel gas opening (FIC684.MV) ~ offers long-term advantage from maintenance.
Prashat Dube is working as Senior Process Engineer at Mathura Refinery, Indian oil Corporation Limited, India and is primarily responsible for rendering technical services for Advanced Process Control implementation and maintenance. He has 4 years of experience in APC for all the major process units at Mathura Refinery. He holds Bachelor degree in Chemical Engineering from Indian Institute of Technology, New Delhi, India.

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