Challenges in Refinery Optimization – User Perspective

Simulation for Business Excellence – SE User Conference

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Content

- Reliance – at a lance
- Optimize in Real Time - Preamble
- Brief Introduction to RTO
- Reliance Experience & Initiatives
Reliance – At a Glance

$62.2 billion
₹3,88,494 crore
Annual revenue

$3.8 billion
₹23,566 crore
Net Profit

148
Major products & brands across energy & service sectors

2nd Largest
Producer of polyester fibre/yarn, globally

5th Largest
Producer of PTA, globally

6th Largest
Producer of PP, globally

7th Largest
Producer of PX, globally

8th Largest
Producer of MEG, globally

12
Conventional E&P blocks

2,621
Retail stores across India

Jio
Setting up pan India telecom network to provide high speed internet and digital services

Largest Refinery complex globally at a single Location—1.4 MMBPD of Crude Processing
Challenge: Optimize in Real Time – Preamble

✓ Agility
  ✓ Create system to capture opportunities as they arise
  ✓ Streamline People process
  ✓ Provide in time correct economic information

✓ Model Accuracy
  ✓ Unit RTO Models need to mirror the real plant
  ✓ Reactor models need be fast, robust, and complex enough to capture economics with mathematics amenable to easy optimization
  ✓ APC models need acceptable fidelity
  ✓ Inferential needs wide range applicability
Challenge: Optimize in Real Time – Preamble

- Integration
  - Planning and Scheduling system integration with APC/RTO
  - Blending System integration with Scheduler, RTO and APC
  - Orchestrating a complete refinery wide optimization and control solution

- Expertise
  - Shortage of good engineers resulting in sub optimal solutions, not realizing full economic potential.
    (Knowledge of operation, technology, engineering, DCS, instruments, economics & vendor tools are required)
  - Technical Services – Lack of taste for optimization and open equation software
Available Systems – Preamble

- Advanced process control (APC)
  - APC software -- Mature and good record of success
  - Inferential software -- Accuracy issue

- Real Time Optimization (RTO) systems
  - RTOs -- Varied degree of success
  - Integration to APC -- Minor customizations required
  - RTO Analysis -- Not mature
  - RTO Reporting -- Needs customization

- Planning & Scheduling System
  - Planning Software -- Difficult configuration, no GUI & Stream properties
  - Scheduling Software -- Runs un-constrained, difficulty in modelling all aspects of operation & people process
  - Blenders -- Analyzer Reliably issue
**Introduction: Control Hierarchy**

**Planning**
- Weeks & Months
  - Simple, Enterprise wide & Steady state

**Scheduling**
- Days
  - Simple, Site wide & Steady state

**Optimization**
- hrs
  - Rigorous, Plant wide & Steady state
- min
  - ROMeo
- msec
  - Empirical & Dynamic model, DMCplus

**DCS**
- Multiple or single loop no Model
- Instrument & Plant
APC - Limitations

**Features:**
- Dynamic Plant Model
- Regressed Model from plant data
- Optimum always at constraints
- Linear Objective & Constraints (LP or QP)

**Limitations:**
- Linear Gain Models
- Linear Cost Function
- Limited First Principle Modelling
- Optimum always at constraints
RTO – For Floating Optimum

- Safety
- Equipment
- Quality

Fundamental Model from first principles
Steady State Plant Model
Optimum floating
Nonlinear Objective & Constraints (QP)
Needs Steady State Detection
Sequential Mode Solvers (SM) – Aspen Plus, Petro-SIM, PRO II, UNISIM, HYSYS

- Initialization is easy
- Can solve differential equations for Reactors
- Solves one by one and proceeds
- Needs different solving algorithm for each equipment
- Difficult to solve for recycle streams and heat integration
- More difficult to optimize
- Still more difficult to respect constraints
**Types of Simulation - EO**

**Equation Oriented Solvers (EO)** – Invensys Opera, Aspen DMO, Honeywell NOVA

- Calculate inputs
- Give outputs

- One solving algorithm for complete plant flowsheet
- Easy for recycle streams and heat integration
- Easy optimization and constraint handling
- Difficult to initialize
- Needs equation and variable information
- Needs special reactor model consideration
- Solves only algebraic equations
What is SM & EO

SM - Closed Equations

\[ Q = U \times A \times LMTD \]
\[ U = \frac{Q}{A \times LMTD} \]
\[ LMTD = \frac{Q}{U \times A} \]

\[ \frac{dF}{dV} = -r_i \]

Features:
- Here 3 formulation for one equation
- Would needs 3 different solving algorithm
- Only Simulation

EO - Open Equations

\[ 0 = Q - U \times A \times LMTD \]

Features:
- One formulation for one equation
- Same equation for: Simulation Parameterization, Data Reconciliation & Optimization
- Needs variable information (const & Calc)
### Variable Definition (Const & Calc):

\[
\begin{align*}
0 &= 3 + 4X_1 + 5X_2 + 7X_3 \\
0 &= 2 + X_2^2 - 2X_4 \\
0 &= 4 + 9X_1 + 3X_4 \\
0 &= 6 + 5X_1 + 4X_3
\end{align*}
\]

- Input variables need to be defined as constants.
- Output variables need to be defined as calculated.

### Sparsity Matrix

<p>| | | | | |</p>
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Variables location in an equation needs to be defined in a sparsity pattern. Only 2% or less non zeros are there in process plants. Sparse Matrix Algorithms Reduce memory requirement and computational time.

### Jacobian Matrix

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Direction required to solve the equations is defined in a Jacobian matrix. These are slopes or partial derivatives, generally determined analytically.

A second order numerical derivative information is defined in a Hassian matrix that is calculated from derivative information.


**Additional Requirement for Reactors in EO**

- Reactor Models are Differential Equations
- EO Solves only Algebraic Models
- Differential Eqs. are converted to algebraic Eqs. by collocation

**Example:**

\[ y = \ln(x) \]
\[ \frac{dy}{dx} = \frac{1}{x} \]

at \( x=1, y = 0 \)

Assumes a solution equation as:

\[ y = a + bx + cx^2 \]
\[ \frac{dy}{dx} = b + 2cx \]

at \( x = 1, \frac{dy}{dx} =1 \)

& \( x = 1.1, \frac{dy}{dx} = 1/1.1 \)

\[ y = -1.4545 + 1.909^*x - 0.4545^*x^2 \]

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<th>( x )</th>
<th>( \frac{dy}{dx} )</th>
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<tr>
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<td>( \frac{dy}{dx} )</td>
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Spline 1 Collocation Spline 2
Automatic RTO Sequence

Selected Plant Measurements

Measurements
Economic Values
Controller Limits
Control and opt. Status Info.

Plant Steady?

No

Wait one Minute

Measurement Validation

Less than 1 minute

Data Reconciliation / Parameter Calculation

15 minute

Optimization Calculation

10 minute

Plant Steady?

No

Implement Optimization points (Ramper)

Line-Out period 60 minutes

Selected Plant Measurements and Controller Limits

Measurements
Economic Values
Controller Limits
Control and opt. Status Info.
RTO Solver Algorithm

- Sequential Quadratic Programming

1. Given $X_k$, Set $k = 0$
2. Evaluate Functions and derivatives
3. Compute search direction, $\Delta X_k$
4. Check for convergence
5. Compute step length, $a_k$
6. Set $X_{k+1} = X_k + a_k \Delta X_k$
   
   $k = k + 1$
   
   Go to step (2)

Sort of Newton Raphson with variable step size
RTO Additional Considerations

1. Normalization of Variables to account for Units of Measure
2. Normalization of Equations to avoid difference in numerical values
3. Smoothing thermodynamic discontinuities (Complementarity)
4. SM Initialization Model for filling initial values
6. Configuration of Objective Function (Merit Function)
7. Configuration of Online sequence logic
8. APC, Data base, DCS and Users connectivity
9. Pricing and Quality information gathering and report generation
10. Steady State Detection
RTO Recap

- RTO is used to capture a floating optima that is not easy to calculate
- Recycle and heat integration in Closed Equation model is cumbersome and on many occasions impossible to use for optimization purposes
- Open equation models need good initialization and special consideration for Reactors
- RTOs need current Prices, feed quality information and requires more attendance
Initiatives @ RIL

APC initiative
- STAR Corporate License in 1994
- SMCA PMD License in 1994
- DMCplus HMD Cracker unit License in 1998
- DMCplus Corporate License in 2001

RTO initiative
- NOVA RTO Corporate License in 1997
- Aspen RTO unit License for HMD Cracker 1999
- Aspen RTO unit License for JMD FCC 2006
- ROMeo RTO Corporate license from Invensys 2012

Current Activities
- In-house implementation group for both APC and RTOs
- More than 800 pages APC/RTO manual written to standardize procedures
- Use of First principle based inferential for use in APC
- Development of reactor models for use in RTO
- Monitoring KPIs and Dashboard
- Expanding use of Open Equation based models for debottlenecking and troubleshooting
- Develop integrated methodology for refinery wide control
Our Experience

- APCs for Operator entry and control at Refinery wide level – Refinery Co-ordinating Control (RCC), Refinery Co-ordinating Optimiser (RCO)
- Graceful system degradation at each level, (DCS, APCs, RTO, RWO)
- Simple enough so that it is amenable to human understanding
Our Experience

☑ Start from product dispatches and product specs and work back

Refinery Coordinating Controller – RCC Diesel Pool

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
<th>Value 5</th>
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Aim to build one detailed model of each unit to rely on if the RWO is simplification.
Current Focus

✓ RWO model to solve within reasonable time by using
  ✓ Simplified Reactor
  ✓ Simplified Column models
  ✓ Less rigorous energy balance
  ✓ Reduced constraint set
  ✓ Component balance &
  ✓ Stream properties calculation
Optimization & Control Scheme

Long Term Planning & Scheduling
Wide Assay Applicability for Buying

LP Planning & Scheduling
Narrow Assay Applicability

LP Embedded in Scheduling

Closed Loop Header Property Control

Manual
Base + Delta Vector

Automated
Base + Delta Vector

Constraint Violation

Feed Blend Optimizer

Scheduling

Product Blend Optimizer

LP Embedded in Scheduling

Plant Constraints

Refinery-wide Simplified Optimizer (RCO)

QP Embedded in Scheduling

Refinery-wide Coordinating Control (RCC)

Quality

ET

Unit RTO

Unit APC

Unit RTO

Unit APC

Unit RTO

Unit APC

DCS

• Refinery Wide Optimizer (RCO) to guide APCs
• Blending & Scheduling system to Guide RCO

• Independent Layer for human analysis
• Graceful system degradation with each layer

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Centralized RTO Setup @ Reliance

- Pool of servers at Central Location
- User login from all Sites
- All project work at one place
- Initial commissioning backup

- All Configuration work by Reliance Engineers
- Consulting services from Invensys & KBC for initial projects
### Monitoring KPI and Dashboard

#### RIL APC Performance Dashboard

**JMD - SEZ - Site APC Performance:**

MVMPI: Excellent > 85%, Very Good >75%, Good >65%, Fair >60%, Poor >0%

<table>
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<th>No of MVs</th>
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<th>MVMPI %</th>
<th>Benefit (Cr/annum) Actual</th>
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**Profit making potential compared to design is about:**

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## Monitoring KPI and Dashboard

### RIL RTO Performance Dashboard

**RIL RTO Performance**

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<th>SI No</th>
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<th>ETMPI %</th>
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**Profit making potential compared to design is about:**

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Summary

- Look at these systems as repository of knowledge and company's learning
- Create in-house implementation group
- Expand the use of models to plant debottlenecking and troubleshooting studies
- Involve operations, technical services, schedulers and planners, it indicates the success level of installed system
- Involve top management for Focus, attention, and visibility as objectives of stake holders are varied and sometimes clash with each other because of safety, economics, reliability and comfort level
Thank You!