New Approach to Refinery Crude Switch Optimization using Profit Suite and Unisim

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Introduction

• New Approach to Refinery Crude Switch Optimization
  – Integrated approach using Profit Controller & Unisim
• Crude Switch and APC applications
• Crude Switch Optimizer
  – Solution Approach
  – Application Deployment
• Results & Future Directions
Crude Switch and APC Applications

- Global uncertainties in crude pricing and availability and product demand
- Refineries process crudes of varying types and compositions
- Advanced Process Control (APC) implementation is very common in Crude Distillation unit (CDU)
  - APC strategies are designed for a fixed set of crudes
- During crude switch, CDU product properties change drastically depending on the crude type
- Crude Switch affects the APC performance and can drastically reduce the benefits
Crude Switch and APC Applications

• During crude switch, accurate and reliable inferentials for product properties are not available
• Soft Sensors predictions for product qualities are way OFF and hence poor control performance
• APC applications are turned OFF during a crude switch
  – Throughput reduction and off-spec products
  – Can extend up to 6-8 hours depending on type of crude switch
• Crude switch is a transient control problem affecting CDU operation
Crude Distillation Unit – Control Overview

• CDU is a highly complex interactive unit with more constraints to honor than variables to adjust

• APC Objectives
  – Maximize Products
  – Meet product specifications
  – Minimize Fuel Gas

• Constraints:
  – ASTM 90% Cut Points – Naphtha, Kerosene, Gas Oil
  – Flash Point – Heavy Naphtha, Kerosene, Jet Fuel
  – Overhead Condenser duty, Overflash, etc
APC in Crude Distillation Unit

- Top Temperature Control
- Condenser Duty Calculation
- Product cutpoints
- Product qualities
- Overflash
- Tower flooding
- Valve positions
- Tower pressure
- Furnace COT
- Product flowrates
- Pumparound duties
- Feedrate
- TC
- FC
- TI
- MVs
- CVs
- AI
- Non-linear Level Control
- Furnace Duty Control
What happens in CDU during Crude Switch?

- Crudes are characterized by True Boiling Point curve (TBP) that determine the product yield.
- Product draw temperature determines the product cut point temperatures and thus quality.
- Change in TBP curve occurs as the new crude hits the column.
- This alters temperature profile in the column and product cut points used to infer product quality.
- TBP curve of the actual crude processed changes continuously; difficult to calculate the product properties.
- As a result, APC is switched OFF during crude switch!
Crude TBP Curve during Switchover

Crude TBP Curve changes drastically!
Existing Solution for handling Crude Switch

- Use rigorous equations to estimate a linear TBP curve using heat balance and temperature profile of the column.
- Naphtha cutpoint and flashzone cutpoint fix the TBP curve.

**Drawbacks:**

- Straight line approximation leads to some error in TBP calculation.
- May not be so accurate when going from very heavy to very light crudes or vice versa.
- Does not consider mass balance, pumparound, and fractionation effects.
Crude Switch Optimizer Solution (1)

• A rigorous simulation model in Unisim Design based on first principles
  – Calculate crude product properties during crude switch based on actual crude composition

• Unisim Socket Bridge to integrate offline Unisim Design with online Profit Controller
  – Extract the inferential properties from Unisim model and provides to Profit Controller
  – Automate execution of Unisim model in every execution of Profit Controller

• Crude Switch Optimizer Toolkit is "plugged on" to Crude Unit Profit Controllers
Crude Switch Optimizer - Workflow

Crude Switch Optimizer Toolkit

Profit Controller 1
Profit Controller 2
Profit Controller 3
Profit Controller n

USD Socket Bridge

Unisim Design Model

First Principle Model
- Vapor Liquid Equilibrium
- Mass Balance
- Energy Balance
- Component Balance
- Property Calculations

Crude Feed Selection
- Crude 1
- Crude 2
- Crude 3
- Crude N

Crude Switch Optimizer Workflow
Operator selects the Crude type being processed and switched over, ‘Mixed' crude being one of the options

Crude Switch Optimizer coordinates the USD Socket for crude type and Unisim model to be invoked

Profit Controller provides column operating conditions (Flows, Temperatures, Pressures) to Unisim model

Unisim model calculates accurate product properties based on column conditions and actual crude mix

Profit Controller runs based on accurate inferential for provided by Unisim model

Since based on First Principles, robust enough to work through crude switches for any crude types
CDU Unisim Design model

- Rigorous model based on Thermodynamics
- Unisim Crude Oil Characterization module for TBP curve
Unisim - Crude Product TBP Curves

- Utility for calculating TBP Curves and Crude and Product properties
Unisim – Databook

- Databook is connection to USD Socket
- Define Input & Output Process Data Tables
Unisim Socket Workflow

- Socket for real time data transfer between Unisim model and Profit Suite
Unisim Socket in Profit Suite

- Executes at same interval as Profit Controller in URT
- Invokes and executes the Unisim model
Unisim Socket in Profit Suite

- Input Values are passed to USD model

- Output Values are received from USD model
CDU Profit Controller with Crude Switch
Inferentials in Crude Switch Optimizer

Reduction in Crude Switch Transition Time
LGO Draw Flow in Crude Switch
Benefits of Crude Switch Optimizer

• Cuts the crude switch time by half or more (6-8 hours to 2-4 hours)
• Reduction in give-away on key product qualities
• Push to maximum constraints and maintains high throughput
• Typically over $1-2m/year extra benefits from APC
• Robust enough to work through crude switch for any crude type
• Can handle new crude types and changes in crude composition
• Benefits are more significant for refineries that processes diverse crude types
Future Work

• Current application uses Unisim Socket “Simulation” mode for Inferentials

• Extend Unisim Socket for other Execution Modes:
  – Gain Extraction:
    • Online Gain Update
  – Optimization:
    • Crude Pricing based optimization
  – Data Reconciliation:
    • Online data reconciliation & Optimization

• Can be used in other Refinery applications
  – FCC Reactor Yield calculations

• Beta Sites !