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Crude Distillation Unit Optimization

Using ORTO Agents

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Background

Optimization of process units has been applied since the late 1970s. Initially, companies applied optimization in open loop, but this was found to be ineffective as operators often did not implement the recommendations or only implemented some of the recommended changes. In most cases today optimization is applied in closed loop. Over proceeding decades, projects have been shown to improve economic performance by 2-5% with occasional projects delivering savings as high as 20%.

Most closed loop optimizers use some form of model as the basis for the optimizer. Models can be determined using first principal approaches or empirically using plant data, often created by plant tests. More recently machine learning and AI-based methods cannot extrapolate, so often require models to learn how to optimize the actual process across the full operating envelope.

The difficulty with model-based methods is that they require significant expertise to build the model and significant amounts of time. Furthermore, as the plant changes, the process-model mismatch increases. This degrades optimizer performance, forcing the reidentification or rebuilding of the model from time to time.

Historically, closed loop optimizers have been applied to many of the major units in oil refining and ethylene production, with some applications in other industries. The applications have been limited by:

1. The cost of building the optimizer and meeting return on investment criteria
2. Lack of expertise

In addition, as the mismatch between the model and process increases, optimizers often fall into disuse again for cost and expertise availability reasons. Consequently, it is generally thought that only 10% of potential optimization applications are successfully targeted and maintained.

ORTOmation has developed a novel approach to closed loop optimization which does not require a model of the process to be developed and maintained. This has several benefits:

1. Lower cost of ownership
2. Less expertise is needed. Typically, existing resources have sufficient skills
3. The time to value is significantly shortened
4. Overall payback time is increased

Working with a company wanting to evaluate the ORTOmation's technology, a digital twin of a crude distillation unit was selected as a trial application. The digital twin was operated at five times real-time speed. This paper provides an overview of the unit, work done, results and possible next steps.

Crude Distillation Unit Overview (Refer to Figure 1)

The crude distillation unit simulated in the digital twin is typical of many crude units. A summary of the layout of the unit is as follows:

1. Crude is pumped from crude storage tanks to the initial preheat circuit.
2. The initial preheat circuit heats the crude by exchanging heat with product rundowns and fractionator pump-arounds.
3. The preheated crude enters a desalter and water is separated.

4. The desalted crude passes to a flash drum, and the flash drum bottoms pass to final preheat before passing to a fired heater.
5. The heater effluent enters the crude unit fractionator for separation into intermediate products.
6. Naphtha leaves the overhead of the fractionator where is partially condensed. Some of the condensed naphtha is recycled to the top of the fractionator to enable control of the top temperature. Gas is separated and compressed and then, after further separation is combined with naphtha and flows to a naphtha separator or passes to offgas.
7. There are three sidedraws: kerosene, light gas oil, heavy gasoil. Liquid that is not removed from the heavy gas oil sidestream passes as overflash to the bottom of the column and combines with any crude leaving the first heater that has not evaporated.
8. Each side draw and the fractionator bottoms have stripping steam injected into strippers to remove light ends and return to the fractionator
9. Sidestreams pass from the steam strippers through heat exchangers which preheat the crude feed.
10. The fractionator has 3 pumparounds to enable control of the gas/ liquid rates in different sections of the column. The pumparounds exchanged heat with the preheat circuit.

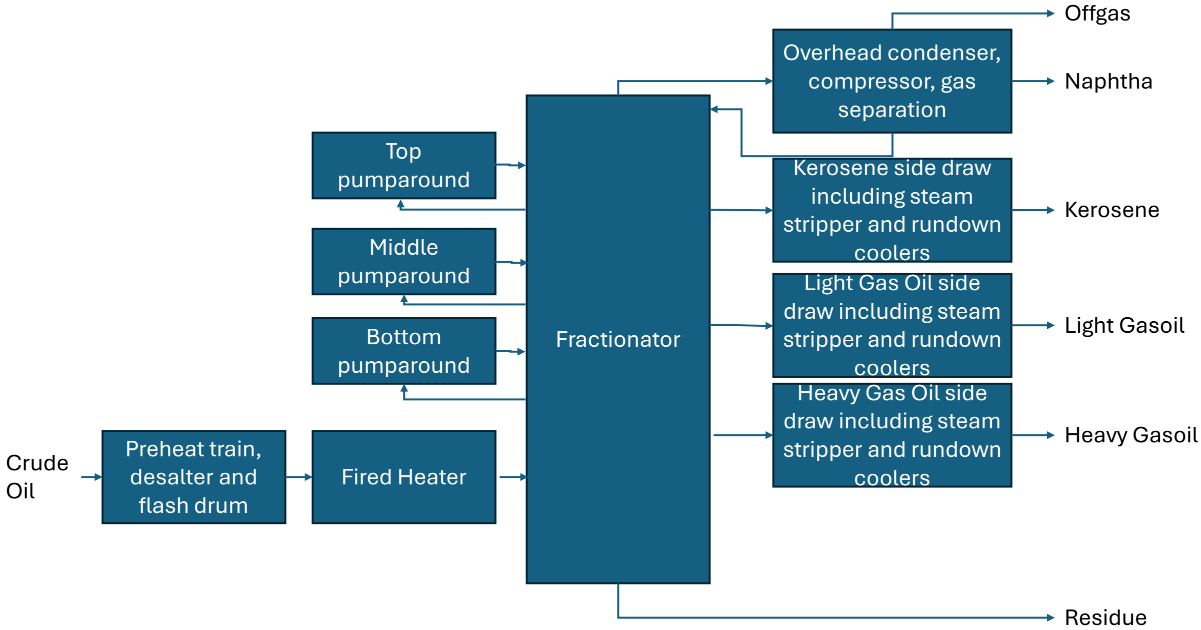

Figure 1 – Crude Distillation Column Block Diagram

Scope of Trial

One significant advantage of ORTOmation optimization technology is that it is agent based. Agents work to drive towards the commonly defined optimum whilst managing any constraints associated with that agent (note, constraints can be the same for all agents or vary between agents). A result of this is that a process unit optimizer can be implemented incrementally instead of having the implement the optimizer over the entire process. The optimization solution can then be extended by adding further agents.

For this trial, it was decided to initially optimise the top of the fractionator. Agents were built to maximize a designated economic cost function, consisting of the product values (naphtha, kerosene, residue) and associated an energy cost (stripping steam flow). Each agent adjusted one of four variables: tower top temperature, kerosene draw, column pressure and kerosene stripping steam flow.

Constraints included:

- Agent output limits
- Tower top dew point temperature
- Naphtha 95% distillation point temperature
- Kero flash point temperature
- Kero 95% distillation point temperature
- Kero freeze point temperature

After successfully setting up the OPC communication and defining the optimization objective function, the optimizer was built in less than half a day. All agents were then commissioned simultaneously, with some minor adjustments to tuning constants to improve performance made thereafter.

<u>Results</u>

To help speed up the trial time, the crude distillation unit digital twin was set to run at five times real-time. However, due to limited availability of the digital twin, runs were limited to a few hours.

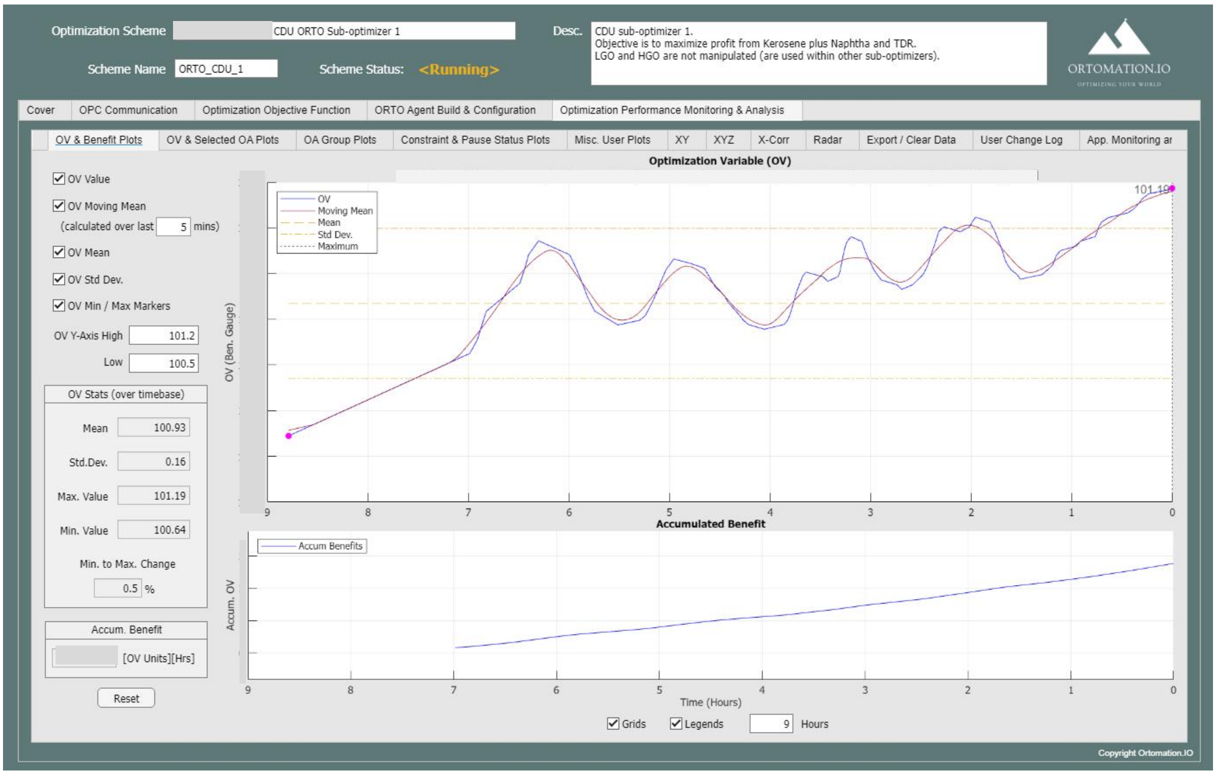

Figure 2 – Optimization Variable Value (Designated Cost Function)

In the ORTO display shown above in Figure 2, the optimization variable value is shown in the top trend over nine hours along with the total accumulated benefit in the lower trend.

The value of the optimization variable increases from the start of the simulation (on the left of the trend) to the end of the simulation (on the right of the trend). For confidentiality reasons, units of measure and values have been removed from the data.

Some points to highlight:

- Over the 9-hour period the value of the optimization variable increased by approximately 0.5% but was still increasing as the optimizer searched to improve the economic performance as constraints were met. It should be noted that since the digital twin was running at 5 times realtime, the 9 hour simulation is equivalent to 45 hours of realtime operation.
- The small variations in the centre of the trend are small (~0.1% of the value) as the ORTO agents search to increase the economic performance as constraints are met.

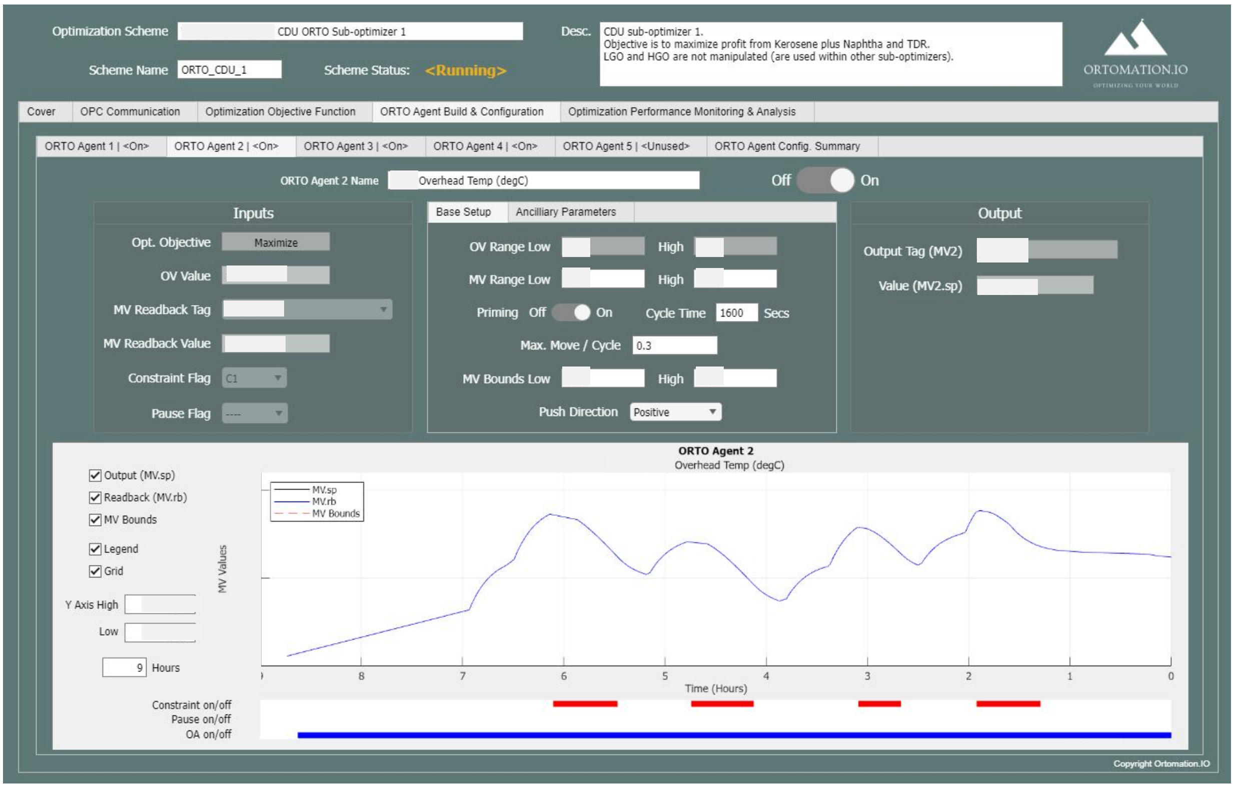

Figure 3 – Tower Top temperature

The ORTO display shown in figure 3 details the optimizer increasing the column top temperature to increase economic performance. Increasing the column top temperature increases the amount of naphtha produced from atmospheric residue (fractionator bottom product) which aligns with economic cost function being maximized.

The red bars at the bottom of the display show when constraints were active on this agent. As can be seen, the agent then adjusts the temperature to stay within the constraint whilst maximising economic performance. The variations are small (~+/-0.1 degree centigrade).

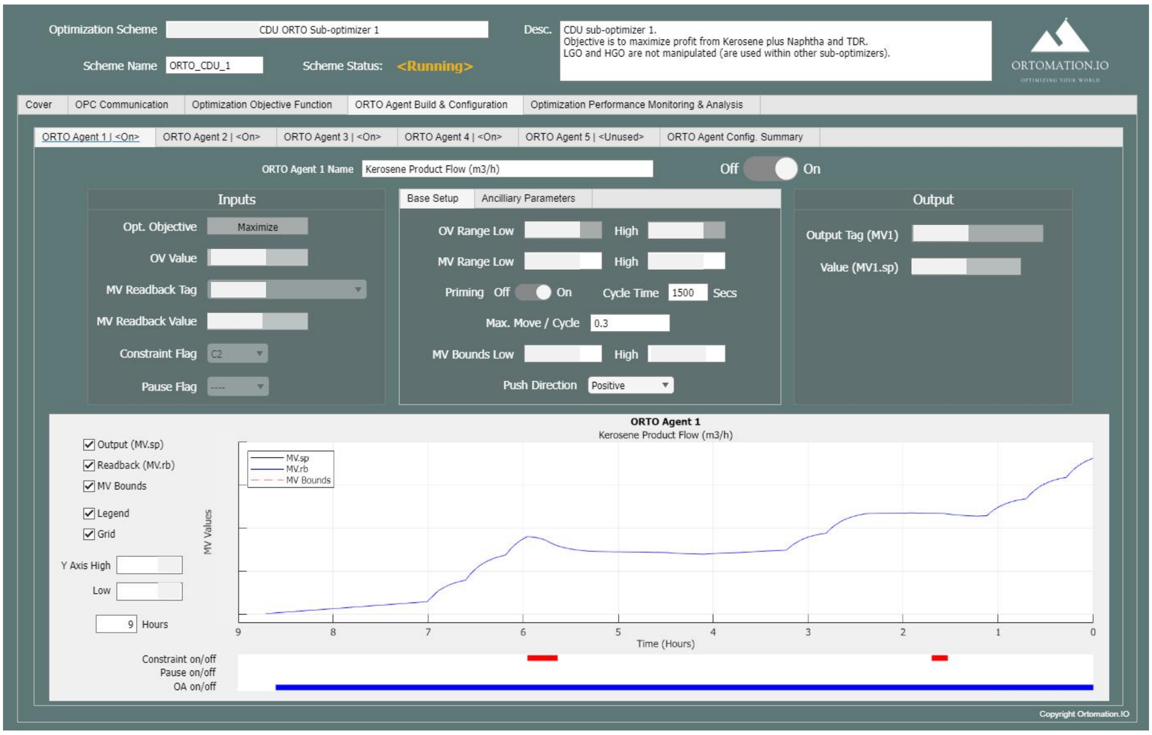

Figure 4 – Kerosene flow

The ORTO display shown in figure 4 details the action of the agent adjusting kerosene flow. As can be seen, the flow increasing consistently over the optimization period with an increase of roughly 4%. There are periods where constraints were active on this agent shown by the red bars. The agent makes small adjustments to return the process within limits.

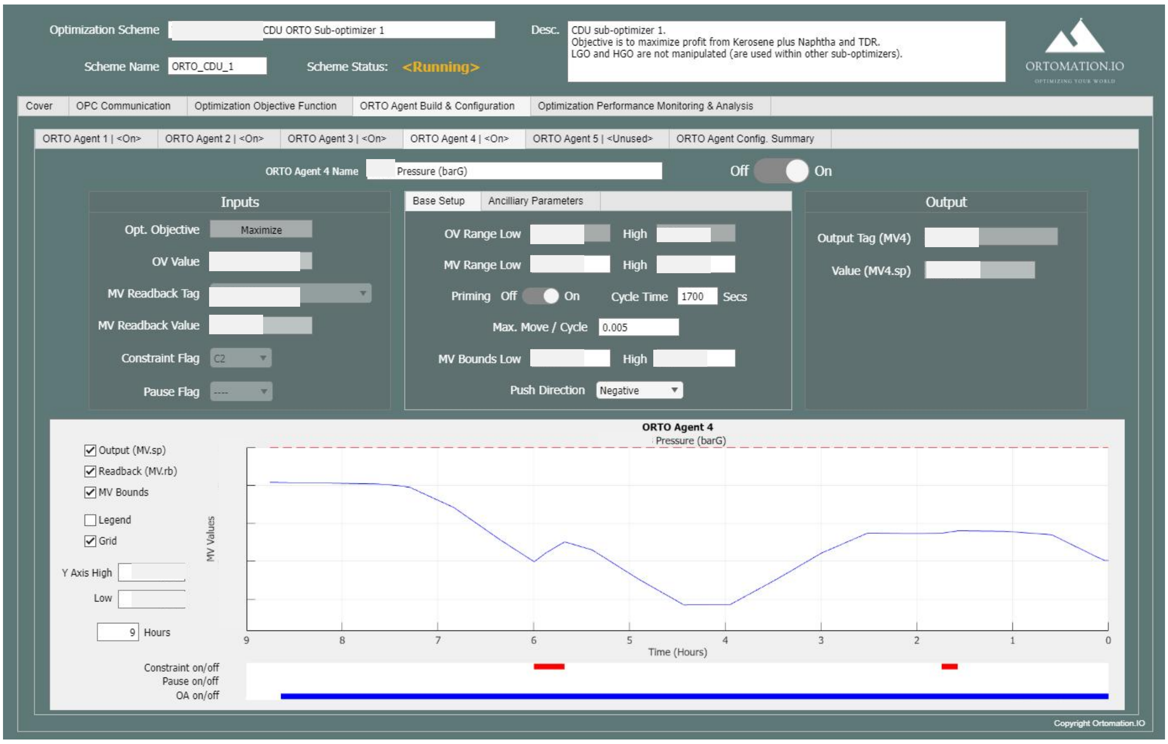

Figure 5 – Fractionator Overhead Pressure

The ORTO display shown in figure 5 details the overhead pressure, which has been reduced over the period of the optimization. This improves relative volatility of the hydrocarbons and improves separation.

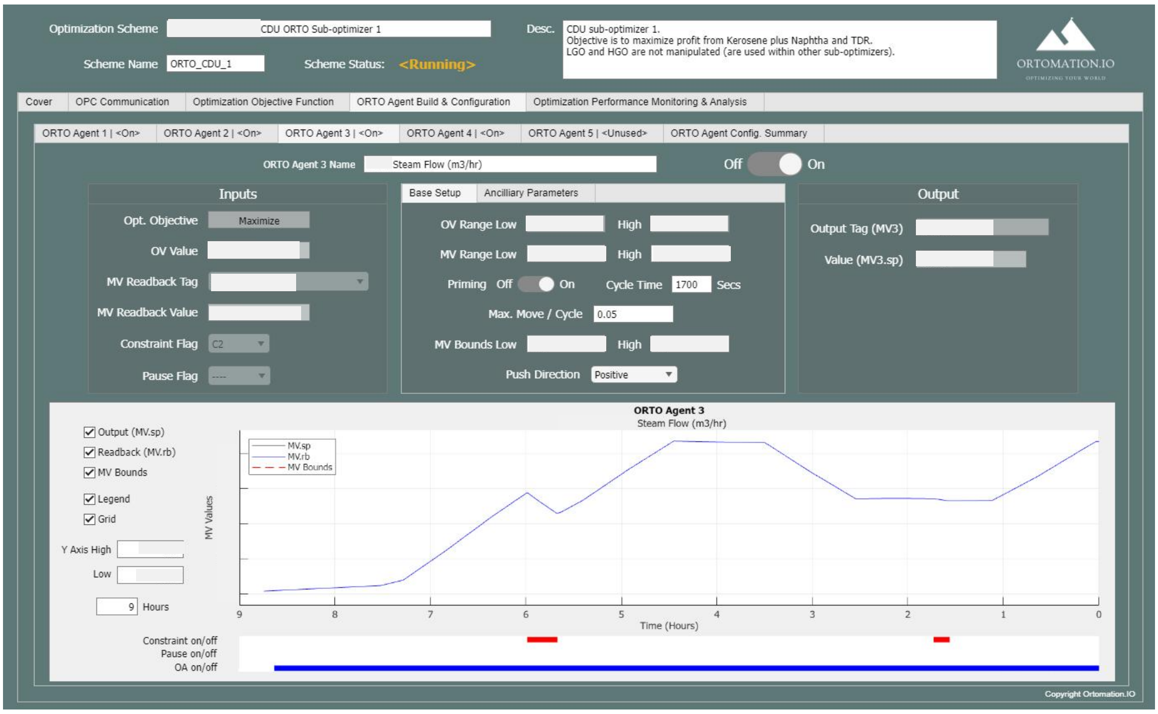

Figure 6 – Steam Flow to Kerosene Side-stream Stripper

The final display shows the adjustments to the steam flow to the kerosene side-stream stripper and the optimizer can be seen to increase the steam flow by roughly 10% over the optimization period.

Conclusions

The application of ORTO agent closed loop optimizer technology successfully improved the economic performance of the section of the crude distillation unit chosen for the trial. No model was required for the optimizer; the ORTO agents successfully learned the impact of adjustments on the optimizer and adjusted for changes in the behaviour of the process over the operation.

The design and build of the ORTO optimizer were shown to be simple. The time needed to configure and commission the optimizer was significantly lower than it would have taken if a model-based approach had been used.

The improvement over the 9-hour period (45 hours simulated real-time) was roughly 0.5%. Constraints were also managed effectively, with ORTO agents navigating around them spatially to improve performance. Although the improvement is lower than commonly experienced in on-process applications (typically 2-5% improvement), it is important to remember that the optimizer was only running for a relatively short period of time, and the optimization variable was still being increased when the trial ended. Also, historical evaluations are usually performed using many weeks or months of data and during these periods many changes and disturbances occur which the optimizer needs to adjust for.

Next Steps

When this case study was written discussions were underway on next steps. Possible next steps include:

- Extending the run-time to allow ORTO to reach the true optimum.
- Extending the optimizer scope to include optimization of:
    - Light and heavy gas oil streams and stripping steam flows
    - Pump around duty split and fired heater coil outlet temperature
    - Feed rate
    - Preheat train flow split
    - Application to an actual crude distillation unit