IMPROVING DELAYED COKER UNIT MARGIN

Jitendra Chellani and Secil Uzun, KBC (A Yokogawa Company), alongside Mohammad Al-Johar and Saravanakumar Chidambaram, SATORP, explore solutions to optimise delayed coker units by increasing throughput and higher-value yields.

In refinery plant operations, ensuring consistent stability and operational efficiency poses a formidable challenge for distributed control system (DCS) operators. This challenge stems from fluctuations in unit feed properties and conditions, influenced by various uncontrollable factors such as changes in upstream operations, variations in ambient conditions, and shifts in unit performance.

Although advanced process control (APC) systems have become commonplace within refinery units, their primary role is to maintain plant stability, rather than guarantee optimised operational outcomes for the entire facility. While APC systems adeptly handle fluctuations within the plant, they fall short of delivering holistic optimisation. This limitation opens the door for Dynamic Real-Time Optimisation (RTO), a solution that calculates optimal setpoints dynamically in response to ever-changing plant conditions. Whether prompted by shifts in plant feed conditions or product price fluctuations, a Dynamic RTO solution can consistently guide and maintain plant setpoints at the optimised operating point.

In essence, RTO represents a significant opportunity to enhance refinery operations by continually aligning these processes with optimal performance criteria. It extends beyond the APC system limitations, offering improved operational efficiency in refinery processes.

Optimisation of delayed coker unit

Refineries worldwide face sustained pressure from volatile crude markets, shifting product demand, and rising environmental and regulatory requirements. In this context, efficiency alone is no longer sufficient; optimisation is essential for competitiveness.

One of the toughest assets to manage is the delayed coker unit (DCU). The DCU is massive in scale and serves as the refinery's workhorse that converts heavy feedstocks into lighter, higher-value products such as naphtha and gas oils while producing petroleum coke as a by-product.

Optimising a coker unit is complex because of its dual operating modes: semi-batch coke drum operation alongside continuous fractionation and downstream processing. This mismatch in process dynamics creates unstable conditions and inconsistent yields.

Due to the significant price differences from the DCU products, optimising the yields from this unit can significantly improve refinery economics. The petroleum coke is a refinery's low-value product. Reducing coke yield while increasing the liquid product yield improves gross margins. The DCU's liquid product prices vary. Maximising light coker gas oil typically improves refinery profitability.

There are often benefits associated with increasing the DCU's throughput. Coker units are typically operated close to their maximum stretch capacity. Debottlenecking the coker unit may allow higher refinery throughput or enable the processing of heavier crudes.

Dynamic optimisation

The Dynamic RTO combines the power of first-principles models with an automated online optimiser. The non-linearity of process units is captured through the relationship between different variables. The matrix built from this relationship is used for optimisation, which incorporates other inputs including price sets, APC limits, and actual operating conditions.

The optimiser is flexible and can be configured for a process unit, multiple process units, or the overall refinery complex. The objective function is based on economics, which includes the cost of feedstock, gross product worth, and variable operating expenses. The results generated by the optimiser are used as external targets for the APC which ultimately controls unit and equipment operation through the DCS.

Separating non-linear first principles models from the optimisation improves the solution's robustness. Optimisation is performed regularly without solving rigorous first-principles models. This reduces model maintenance. The two-layer approach ensures that optimisation is performed at specific time intervals without waiting for steady state detection. Steady state detection updates the model matrix dynamically, whereas the optimiser estimates external targets regardless of steady state. A simplified representation of Dynamic RTO is shown in Figure 1.

Case study

KBC (A Yokogawa Company) and Saudi Aramco Total Refining and Petrochemical Co. (SATORP) collaborated to deploy an RTO in the DCU. SATORP operates a high conversion refinery in Jubail, Saudi Arabia, that includes a DCU for residue upgrading. The RTO is part of the advanced analytics programme, which includes a strategic approach for digitalisation.

The RTO deployed at SATORP's DCU uses an innovative approach where first-principles modelling estimates updated gains dynamically. These gains are used by the optimiser to estimate changes in the APC external targets. Figure 2 shows an overview of the first-principles Petro-SIM® process simulation model.

The objective function for the DCU RTO includes gross product worth, cost of feedstock, and unit utilities. The gross product worth is estimated based on product yields and prices. Estimating intermediate prices for the DCU was a challenge during the project execution. The project team agreed on a unified approach to estimate these prices and the price-set was regularly updated and used by the solution for the optimisation.

Optimisation reduces the yield of low-value products while increasing the yield of high-value products. Coke is one of the low-value products from the overall refinery, and the optimiser estimates changes in various manipulated variables (MVs) to reduce coke yield while increasing the yield of liquid products. In addition to yield shifts from low to high-value products, the solution performed yield-vs-energy optimisation.

RTO is integrated within the existing infrastructure. Direct communication between RTO, APC, and DCS reduces manual efforts by the operator. The performance of the solution is monitored by various stakeholders through the dashboards developed for the project.

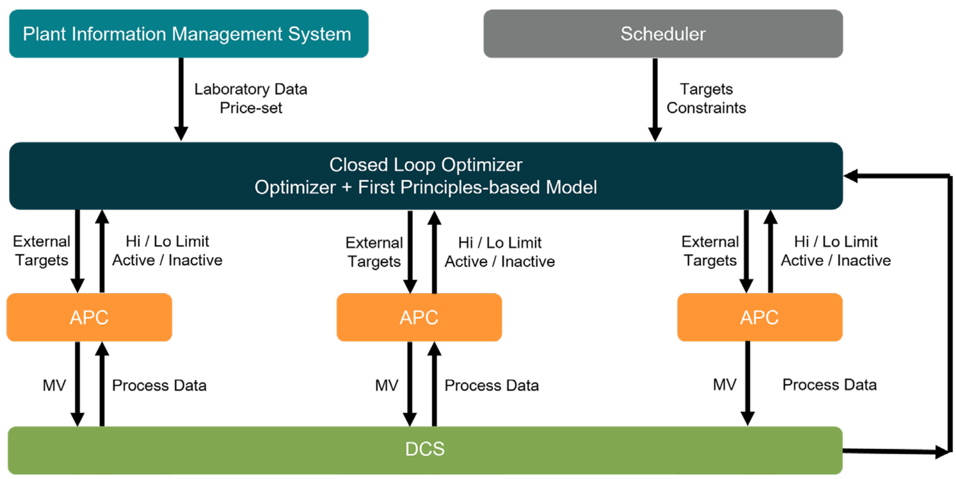

Figure 1. Simplified representation of the Dynamic Real-Time Optimisation (RTO) solution.

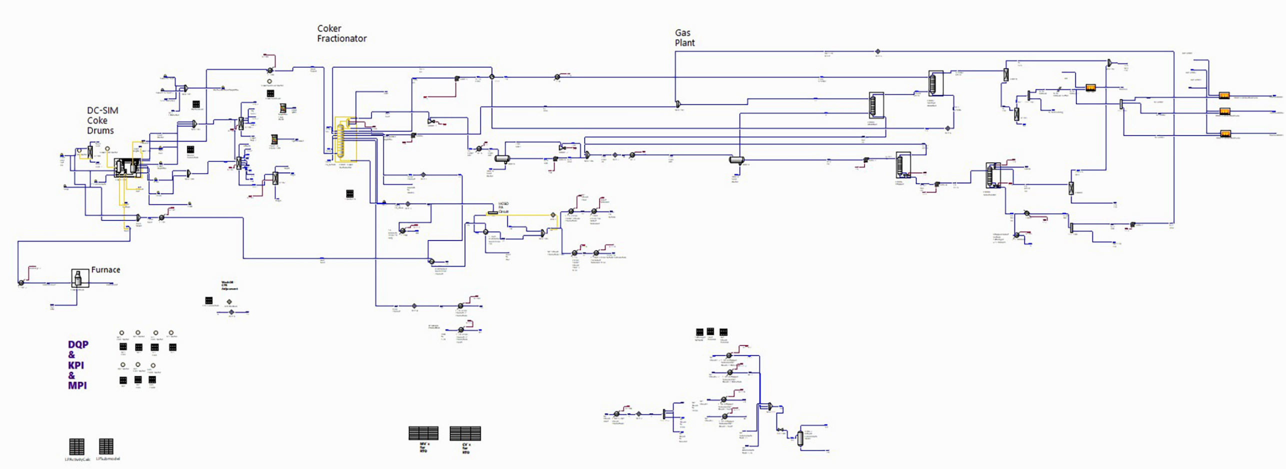

Figure 2. Petro-SIM model for DCU RTO.

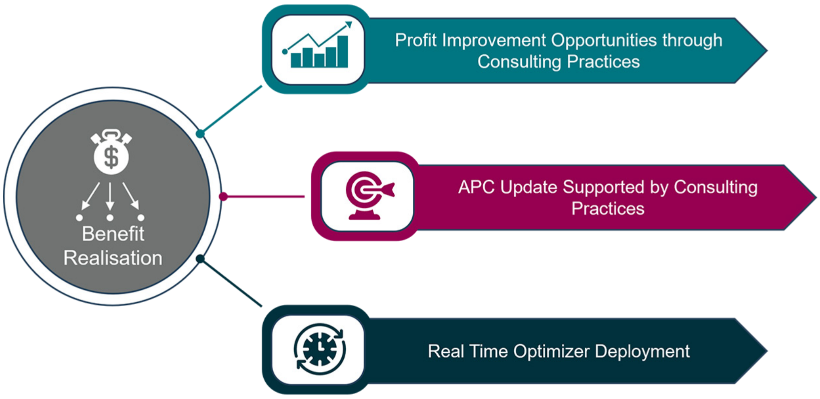

Figure 3. Project benefit realisation.

The solution deployed at SATORP follows the internal cybersecurity guidelines and regulatory standards. Communication between various systems has been established to operate the solution without any manual intervention. The closed-loop optimisation is performed using on-premises infrastructure.

The DCU RTO was deployed as a solution rather than a tool. Different aspects through which benefits were realised in the project are shown in Figure 3.

The solution deployed at SATORP was supported by KBC's consulting practices. Some of the benefits were realised before deploying the solution. Round table discussions, data analysis, and model development identified multiple ideas for improvement. These ideas were screened, and specific opportunities were discussed with the stakeholders.

The APC was also updated based on the functional design prepared for the RTO. The benefits were realised while updating the APC which was also supported by consulting practices.

The benefits from the RTO deployment were estimated at a specific frequency. These benefits were aggregated and available on dashboards. The dashboards automatically prepared management reports, which documented monthly and cumulative benefits since the deployment.

Various opportunities identified through consulting practices were discussed with project stakeholders. Some of these opportunities were implemented before deploying the solution. The programme's payback period was less than three months based on the benefits implemented through these opportunities.

After deploying the tool, additional benefits were delivered. These benefits were tracked automatically through dashboards, which are accessible company-wide. They display both monthly and cumulative benefits.

Sustaining the solution is as important as its development and deployment. End-user engagement and role clarity were achieved through multiple training sessions and workshops. Various work processes for RTO use and maintenance, along with RACI matrices, were discussed.

With the solution framework in place, the next step was to assess its performance under real operating conditions. Post-implementation monitoring focused on whether the optimiser delivered measurable gains in yield, energy use, and profitability, while also improving day-to-day operations. Benefits were confirmed through the project's post-implementation monitoring phase.

Conclusion

Deploying an RTO in the DCU demonstrates that even highly complex, semi-batch refinery units can achieve reliable and sustained optimisation. Applying it in the DCU, one of the most challenging units in refining, demonstrates its potential for broader deployment across other fractionation and conversion units.

The implications extend beyond near-term profitability. As refiners face the dual pressures of competitiveness and decarbonisation, digital optimisation offers a pathway to improve energy efficiency while sustaining economic performance. The programme also identified additional opportunities for future implementation, reinforcing that optimisation is a continuous process rather than a one-time project. In many ways, optimisation should be viewed as an ongoing journey, with each phase building on the last. In this sense, RTO is not only a tool for capturing incremental margin gains but also an enabler of long-term strategic goals.