Allison Buenemann, Imubit, reveals how flexibility is key to developing an effective process optimisation programme.

The secret INGREDIENT

The oil and gas industry is no stranger to doing whatever it takes to get the most value out of its assets. Sometimes this looks like capital investment in plant equipment to add capacity, but most of the time it looks like getting the most out of existing assets, leveraging technology to help decide the most economically favourable or energy efficient way to run a unit. The secret ingredient to cooking up a world class process optimisation technology programme is not a particular technology selected, nor a team hired, but rather, flexibility.

Creativity in optimisation and controls

In operating a hydrocarbon processing plant, there are non-negotiables, particularly when it comes to process safety and environmental risk. Limits are not exceeded, metallurgies are not compromised, and maintenance is not skipped. But there is also a lot of room for creativity in how a plant is operated. It turns out that plenty of different operating strategies can produce fine results. But fine does not cut it in an economic downturn when margins are tight. The evolution of the closed loop controls and optimisation technology landscape has been fuelled by these economic cycles, finding ways for companies to survive in poor economies and thrive in strong ones.

Industry veterans have witnessed the evolution of control and optimisation technologies, from manipulating valves by hand, to basic and regulatory controls, to the gold standard of advanced process controls (APCs) over the past few decades. A variety of online optimisation technologies have been layered on top of APC systems, some highly successfully. While the industry generally agrees that this has been the progression of online control and optimisation, there is also an understanding that no two plants handle control and optimisation exactly the same.

There could be a variety of reasons why so much disparity exists in the way plants are architected for control and optimisation. Blame could reside in the frequency with which assets change hands, the size of the company, or the amount of talent a certain geographical region can draw. The only consistency is the inconsistency, which has put decision power in the hands of individual unit teams, but has historically made it hard to adopt any one approach to closed loop process optimisation across units, sites, and organisations.

Traditional solutions encounter traditional hurdles

As with all digital transformation initiatives, the challenges hydrocarbon processors face when progressing along the evolution of closed loop optimisation and control solutions involve technology, process, and people. Technology challenges arise when attempting to map linear and first-principles based models to real-world refinery processes with significant nonlinear behaviour. But while nonlinear modelling challenges present a significant hurdle to implementing a successful optimisation project, the largest barrier relates to people.

Larger integrated petrochemicals and energy companies have invested heavily in advanced process control technologies over recent decades, building site and corporate competency teams to support deployments. These teams have proven critical to extract value from APC and online optimisation investments. When combined with the cost of the technology itself, however, this resource investment can present a barrier to smaller operators who operate leaner and must be more frugal and calculated in their technology investment decisions.

A data-first approach complements a diverse existing landscape

Using artificial intelligence (AI) for closed loop optimisation begins with operating data specific to the site and the unit to be optimised. Advanced AI model classes and frameworks, such as foundation neural networks and reinforcement learning, are used to construct a model over which the optimiser is trained and built with the knowledge and experience of historical plant operations. This breaks a 40-year-old paradigm of model-building using first principles or generic unit simulation, a process led by one of the most rapidly shrinking areas of expertise in the workforce.

By starting with the specific data for the operating unit, the need for a robust existing process model, based on first principles or simulation data, is alleviated. Eliminating this prerequisite opens advanced optimisation capabilities to companies that did not previously have the capital or resources to allocate towards a large advanced process control project. Unlike traditional online optimisation technologies, which define a strategy that is then executed by an underlying APC system, AI-based optimisation provides the capability to both define and execute the strategy. This inherent flexibility could look like writing set point targets directly to a distributed control system (DCS) or writing external targets to APC.

Advancements in software UX development and autoML have also lowered the barrier of entry for the skillset required to carry out closed loop AI model building. Traditional advanced controls expertise is honed over decades and requires intimate knowledge of the inner workings of the technology. In contrast, point-and-click web-based model building and evaluation environments democratise the model building process to include the full spectrum of domain experts ranging from operations, process engineering, planning and economics, digital and data science teams, and of course, process controls.

The need to formally classify this new category of AI-based closed loop technologies was recognised by ARC Advisory Group. Its 2024 research on the broader optimisation and controls market coined the term Closed Loop AI Optimisation (AIO). ARC defines AIO as the use of machine learning algorithms, such as neural networks, to directly control plant operations based on model predictions. This 2024 research named Imubit as the leader in the overall AIO market category, with a significant footprint in the refining and petrochemical sector.[1]

Figure 1. An interactive model-evaluation environment helps to build SME trust in AI process models, and provides a playground for simulation and what-if analysis.

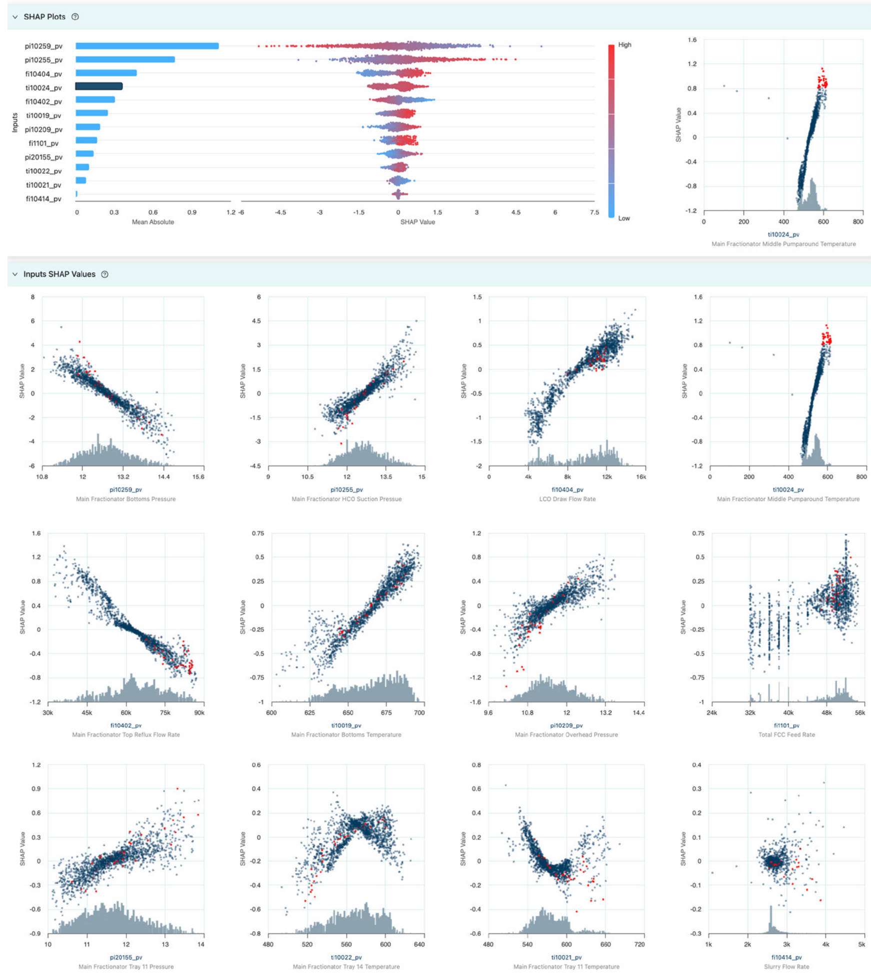

Figure 2. Development of nonlinear inferentials is made more accessible with interactive explainability features such as SHAP plots.

Industry case studies find value in flexibility

The selected case studies highlight the varied challenges faced by hydrocarbon companies. Variable existing technology infrastructure; challenges spanning one process area to system-wide optimisation; the level of in-house control; and optimisation competency all come into play. A solution for each of the companies had to be integrable with different existing systems with a support model that could upskill and empower existing resources or offer vendor or partner support to extend the capacity of the site team. These cases highlight the ability for AIO solutions to overcome the technology, process, and people (or any combination thereof).

Case study 1: petroleum coke refiner

Challenge

One of the world's largest upgraders of refinery co-products knew that it was leaving money on the table in its rotary kiln operations. It was also up against aggressive sustainability targets that it could make significant progress towards by reducing natural gas usage. Its existing closed loop infrastructure did not consist of any advanced process controls or optimisation technologies, primarily due to three major process complexities:

- Variable time dynamics spurred by long kiln residence times made it difficult to monitor and model the impact of key variables on the lab-measured finished quality specifications.
- Inconsistent raw material quality – a result of imperfect methods for mixing solid feedstocks – makes it difficult to understand the impact of different feedstocks on the process.
- Nonlinear relationships between process variables add difficulty to finding optimal operating points.

Solution

Delivering the solution to this challenge required the AIO solution to write set-points directly to the underlying regulatory control layer, managing safe operating limits, key quality parameters, and other constraints. An AI process model built from years of historical unit operating data was able to accurately model the nonlinear relationships between the fuel and air supply with kiln temperature. Reinforcement learning was used to run millions of trial and error simulations on this process model, giving the resulting controller the equivalent of thousands of years of plant experience and the ability to drive towards global optimum kiln operation under any combination of feed quality, equipment constraints, or other disturbances. Deploying this technology took less than six months from concept to closed loop optimisation with no additional headcount required, making it a good alternative to other approaches requiring additional time, services, and in-house expertise.

Results

The closed loop AIO solution detects changes in feed quality and ambient conditions and translates the process relationships learned by the model into dynamic adjustments of air, natural gas, and kiln rotation speed. The stability this adds to the burn zone temperature (BZT) allowed the customer to significantly lower the target BZT, lowering both natural gas consumption and real density giveaway. Ultimately, natural gas consumption per ton of petroleum coke was reduced by 15 – 20% while consistently meeting product quality specifications and improving yield.

Case study 2: small US-based refiner

Challenge

A single-site US refiner was looking to boost margins by pushing more product into the higher value diesel stream.

Historically, various technical, organisational, and plant equipment challenges had made this infeasible. The site runs lean from a personnel perspective, and without an experienced site or corporate advanced controls group to support implementation of APC or online optimisation projects, it had not been able to explore those options. At the same time, frequent tower flooding was forcing the refinery to run with its diesel flash point higher than desired to stay on spec while also making more lower-value naphtha than desired. Because flash point lab sampling is less precise than other tests, its also added a 5°F buffer on the target flash spec, which further reduced diesel make.

Solution

Exploring closed loop AIO, the site discovered an option that would enable it to tie into its existing controls infrastructure without the need to staff up and build an in-house controls competency. The previously frequent tower flooding events were eliminated by improving tower stability with a strategy that simultaneously adjusted reboiler and reflux rates. An accurate inferential for diesel flash point provided confidence to operations that the reboiler and reflux handles could be pushed to drive harder towards the flash targets.

Results

The AIO solution increased operators' understanding of the unit variables and their relationships and ultimately gave them confidence to push the unit with the knowledge that they could do so in a way that avoided quality giveaway or flooding challenges. The conservatism buffer on flash was lowered from 5 – 3°F, a shift which resulted in a 0.4% increase in diesel recovery, adding significant margin uplift.

Case study 3: large US-based refiner

Challenge

A large US refiner wanted to reduce coke giveaway resulting from suboptimal coke drum cycles – cycles when the target level is not achieved in the normal cycle time. The company had implemented many advanced process control and optimisation projects and had exceptional in house expertise at both the site and corporate level. The nonlinear complexity of this problem, however, proved challenging for its existing technology stack. Coke rate is notoriously challenging to measure due to variable upstream feeds and the batch nature of the process. The refiner sought a solution that could accurately predict coke rate and level in the drum, and one that would also take advantage of its existing advanced process control infrastructure to execute the optimisation strategy.

Solution

The site had been watching the market evolution around the use of AI for closed loop optimisation and control and saw this challenge as a perfect test case on a nonlinear challenge that it could not solve with APC. The crux of the project was the creation of an accurate coker inferential. AIO was able to overcome this, creating a reliable inferential that was nonlinear with respect to the furnace rate. This inferential helps the refiner calculate the furnace rate required to achieve the target coke rate needed to fill the drum to the optimal level within the cycle time.

Results

The benefits of the AIO application were tangible in terms of both operations and profit. The site observed a 25% reduction in suboptimal cycles with an average suboptimal cycle improvement of 1.2 ft of coke drum level. This significant impact on overall coke giveaway came alongside excellent operator feedback on the application. The day supervisors and process engineers were unburdened from manually specifying coke rate adjustments as they now had the AIO solution to manage this.

Practical considerations for AIO implementation

Part of being an early adopter of a new technology is reaping the benefits and competitive advantage of being first to implement. Another, equally important, part is learning and developing best practices around the people, processes, and technology that make an AI project successful. Imubit's AIO customers have shared the following insights:

- Have the right people in the room to give a complete understanding of process conditions. While this may seem obvious, missing things like varying process time dynamics and unmeasured disturbances early on can create unnecessary recycle in the model building process if not flagged ahead of time by subject matter experts (SMEs).
- Build operational flexibility into AI models. This is particularly important for system-wide models that span units so that, for example, a single diesel stripper outage does not cause the parent diesel pool model to disengage.
- Lastly, and most importantly, get operator buy-in early for the adoption of any closed loop technology. The most important people to convince in implementing a technology project are the ones who have the power to turn it on and off. Giving operations a level of ownership during the model building process helps to build trust. It also helps to demonstrate that AI technology is not something that will replace them, but rather something to help them learn, improve, and ultimately run the most profitable plant possible.

Conclusions

Leveraging advancements in modern AI technologies for complex closed loop optimisation and control problems offers a flexibility that has not been seen in the past decades control paradigms. With the mathematical rigour to solve complex nonlinear problems, the ability to integrate with any flavour of existing infrastructure, and the ease of use to empower the existing workforce, AIO is providing a flexible, high potential shake-up in the closed loop landscape.

Reference

1. 'Advanced Process Conterol and Online Optimization', *ARC Advisory Group*, (2024).