Cross-unit APC boosts downstream performance

Manipulating advanced process control in a crude unit reduced constraints in a downstream diesel hydrotreater

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How difficult is it for advanced process control (APC) to manipulate CDU (crude unit) parameters in order to alleviate constraints of a downstream diesel hydrotreating unit (DHT)? Theoretically not too complicated, but practically difficult because these units are operated by two different operators. The CDU operator's first priority is to handle CDU constraints while maximising production of the more valuable products (see **Figure 1**). Indeed, there was an APC application in place to help accomplish such economic objectives. As it happens, at Petronas Melaka refinery such a strategy in isolation may cause problems in the DHT unit, forcing a throughput cut, costing the refinery dearly in lost premium diesel production. Where are the APC benefits then?

Management asked the Melaka APC team to mitigate this conflict, adding DHT feed constraints to the CDU APC application, and this article is about how such an order could be accomplished.

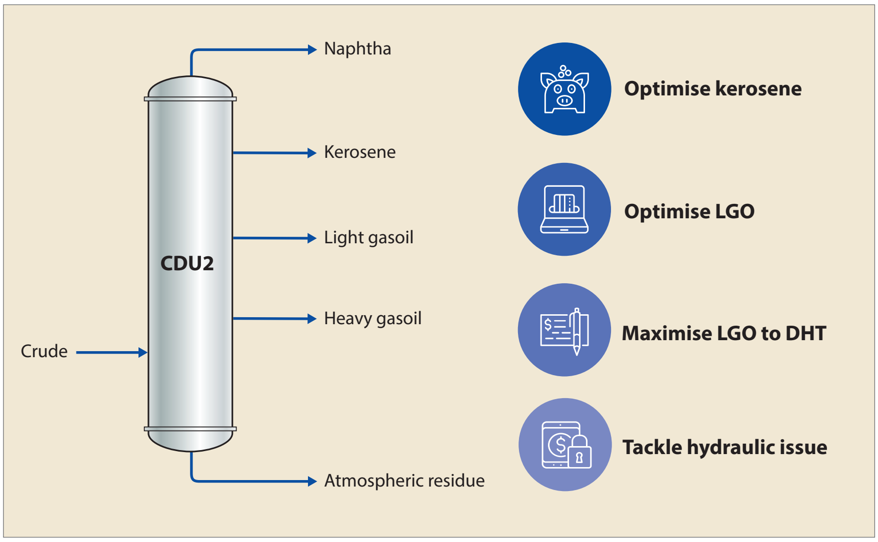

Figure 1 CDU2 products and control objectives

Problem statement

Melaka's 180 000 b/d CDU2 is a high sulphur crude unit, feeding a downstream DHT, a hydrocracker, and a delayed coker. This modern high conversion complex (see **Figure 2**) produces mostly gasoline, jet-fuel and low sulphur diesel oil. It is important to keep all of these units working seamlessly, or conversion or throughput may suffer. **Figure 3** shows the connection of interest here. Light gasoil (LGO) goes to the DHT either directly or indirectly via an intermediate storage tank. Coming into the DHT, LGO is filtered to protect the catalyst. There are two filters in parallel, one active while the other is being backwashed and then in standby. Filter switching should take place no more than once per day. However, feed flow from the tank is often contaminated by a slurry of rust, plugging up the filter, speeding up filter switching sometimes to three times a day, to the point that DHT throughput must be cut in order to reduce switching frequency. Not only is frequent filter switching a major operating inconvenience, throughput reduction also costs dearly in lost premium diesel production.

Can we just simply increase the DHT hot feed draw and reduce tank rundown? It turns out that there are hydraulic constraints. The hot feed valve becomes saturated, and trying to maximise total LGO draw reduces the pump head, worsening the problem. The way to alleviate this situation is to reduce total LGO

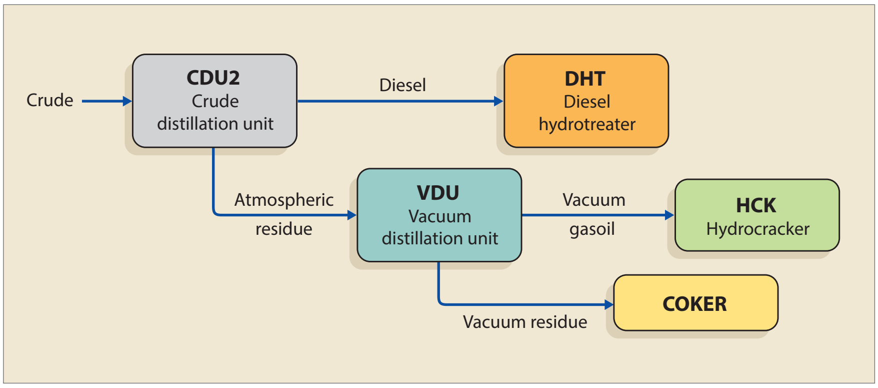

Figure 2 Melaka PSR2 complex

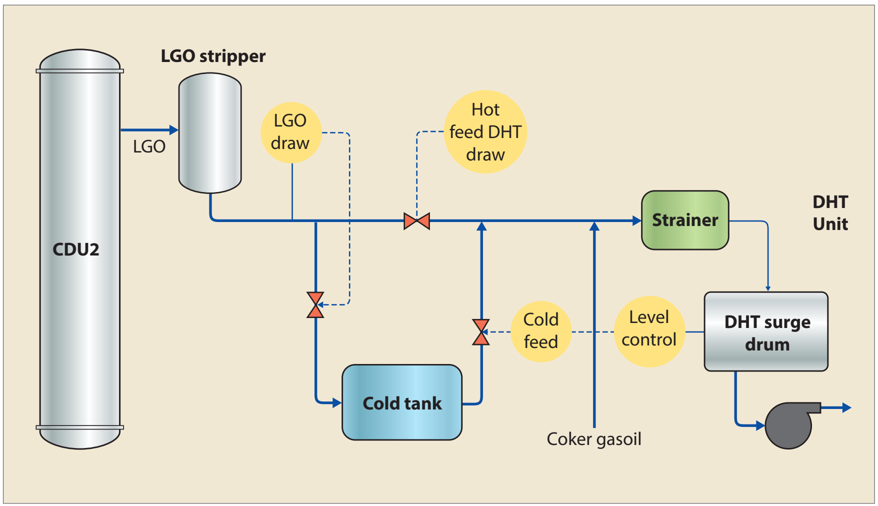

Figure 3 CDU2 LGO connection

draw, sending the excess diesel material either down to HGO and to the vacuum unit or to kerosene, provided kerosene is still on specification. Sometimes we are forced to increase the flow of overhead naphtha, an undesirable product, to reduce LGO yield. This is a complex multivariable constrained optimisation problem.

That was the driving force for configuring the CDU APC to consider DHT constraints. Ideally, the CDU APC should continue to maximise diesel production, but without running much of it down to the cold tank.

Adding to the complexity is light coker gasoil (LCGO), which is also fed to the DHT. LCGO is only 15% of DHT feed, but it fluctuates with coker drum switches, sometimes dropping from 15% to 10% of feed for two hours or so, and that shortage is made up by dirty cold feed

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from tank. This scenario begs for a coker APC drive to minimise LCGO fluctuations. Indeed, we have implemented such control logic, and managed to reduce the fluctuations by letting coker unit levels rise and fall. Nonetheless, there is not enough LCGO inventory volume in the coker to eliminate the fluctuation completely. That coker APC scheme would be the subject of another article.

APC history

Melaka has invested heavily in APC and presently all major units are under APC control. There is a sizable team in place to handle day to day maintenance as well as the occasional APC revamp or new applications. APC is much appreciated by operators and refinery management, and it typically runs at 90% service factor.

CDU2 APC was implemented in 2003 and has remained in closed loop almost continuously since then. It runs on RMPCT (Honeywell's multivariable controller) plus inferential control models based on a Petrocontrol CDU package called GCC. GCC works to identify the true boiling point (TBP) curve of the crude being run from column measurements, and from the crude TBP curve it estimates product properties. GCC is a reliable, well tested, first principles inferential package, and using this package permits the APC to continue working during crude switches. We would not describe GCC further here except to say that several papers have been published about its performance,[1-9] and one of these[5] describes our initial CDU2 APC implementation in Melaka. Over the years, CDU2 underwent revamps and process changes, and the APC has also been revamped to keep it current.

DHT APC was implemented in 2013, primarily in order to control diesel flash point, again a Petrocontrol inferential model. DHT APC was not the main carrier of this cross-unit optimisation drive and hence it will not be covered further in this article.

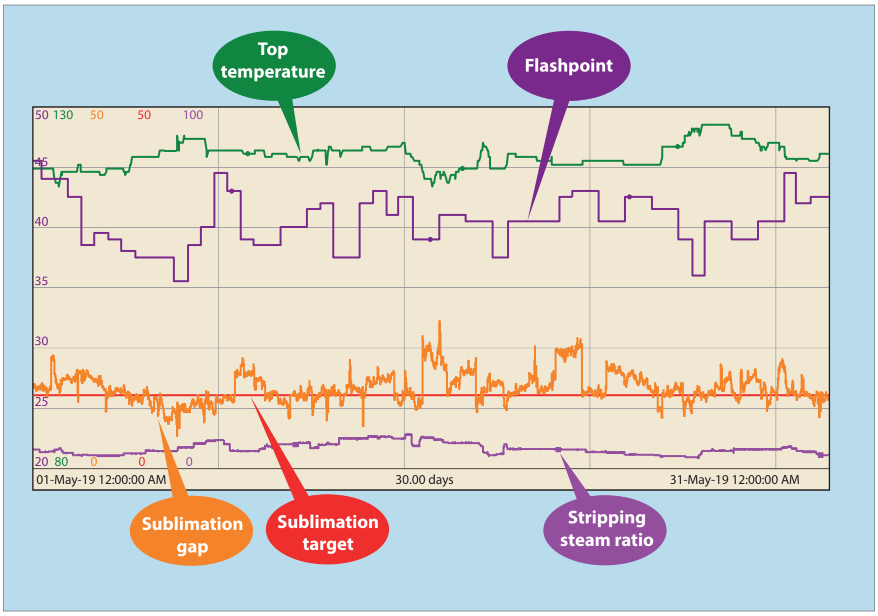

Figure 4a Kerosene flash 30-day trend before APC

Control and manipulated variables

The manipulated variables are typical of CDUs with one addition:

- Top temperature, controlling naphtha cut point

- Side draw flows, controlling side product cut points
- Stripping steam, controlling kerosene flash-point
- Other MVs because the actual application is more complicated than our current description
- The DHT hot feed flow is added; this can be manipulated below the point of valve saturation.

The control variables are also typical of CDUs with some additions:

- Product 95% points
- Kerosene freeze point
- Kerosene flash point
- Top temperature NH_4C_l sublimation point; top temperature must be kept above sublimation point to keep the column top trays clean. To some extent, controlling sublimation point causes kerosene flash point giveaway.
- Other CVs because the actual application is more complicated than this current description
- DHT hot feed valve position; saturation is to be avoided.
- LGO rundown to tank, to be minimised
- And most important, actual DHT cold feed flow, which directly affects filter switching frequency

What this APC has achieved

Sublimation and kerosene flash control

Figures 4a and **4b** show our ability to control top temperature to sublimation limit while avoiding kerosene flash-point giveaway before and after implementation. **Figure 4a** is a 30-day trend before APC implementation, showing:

- Column top temperature (green)
- Kerosene flash-point lab test (purple)
- Stripping steam ratio (magenta)
- Gap between top temperature and sublimation limit (orange)
- Sublimation gap target, 10°C above sublimation model limit (red). The sublimation gap can be about 5-10°C off. Kerosene flash-point is 43-45°C, indicating giveaway of 4°C.

Figure 4b is a seven-day trend showing the same parameters plus kerosene flash-point inference (blue). APC controls the sublimation gap almost precisely to target, while maintaining kerosene flash-point around 41°C. At the time of this test, the flash inference had just been added to the historian and its reliability during those seven days can be questioned. **Figure 4c** is a four-month trend of the flash inference versus lab, showing they do track together well. This APC flash-point improvement indicates yield shift in the order of 1% from naphtha (low value) to kerosene (high value). Over a full year at current prices, that alone is worth several million dollars.

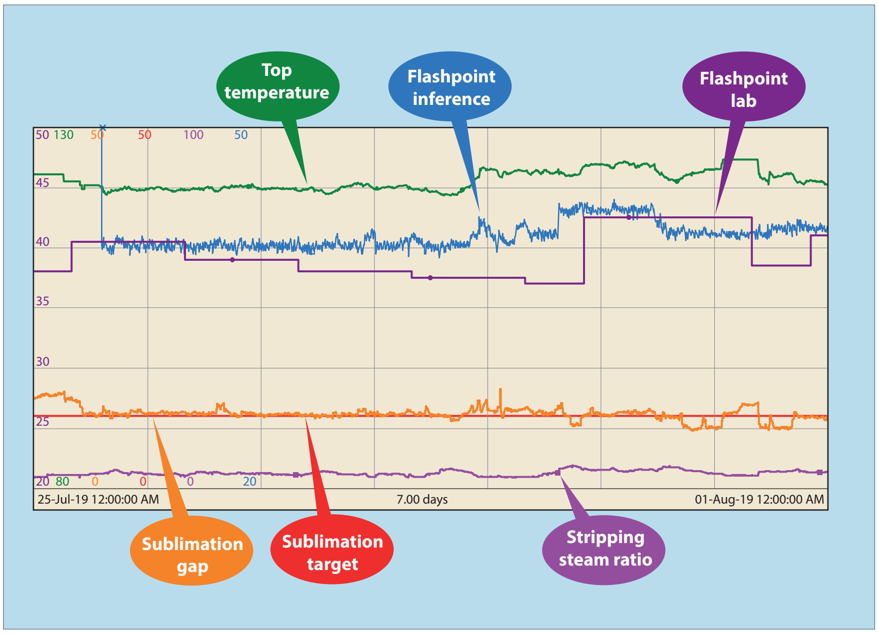

Figure 4b Kerosene flash 7-day trend after APC

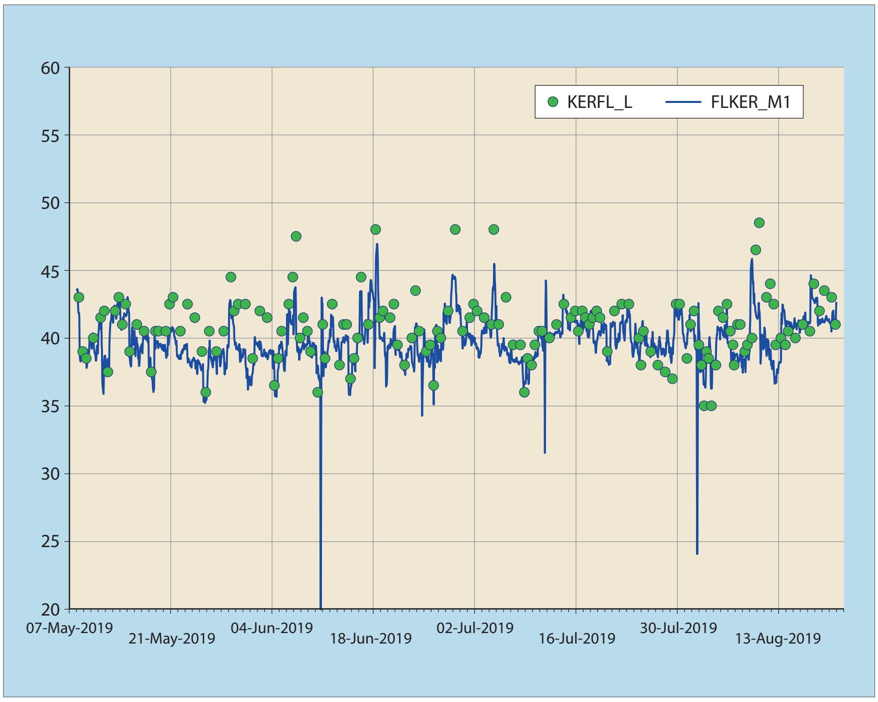

Figure 4c Kerosene flash inference performance trend

Minimisation of LGO rundown to tank

The effects of those CDU2 actions on actual DHT filter switching frequency are illustrated in **Figures 5a** and **5b**, which trend important DHT feed parameters for three days without APC and three days with APC:

- DHT total feed flow (magenta)
- DHT hot feed from CDU2 (green)
- CDU2 LGO production (orange)
- LCGO feed from the coker (red); coker drum switch disturbances, two per switch can be observed
- Cold feed from tank (purple); the response to LCGO shortage is obvious

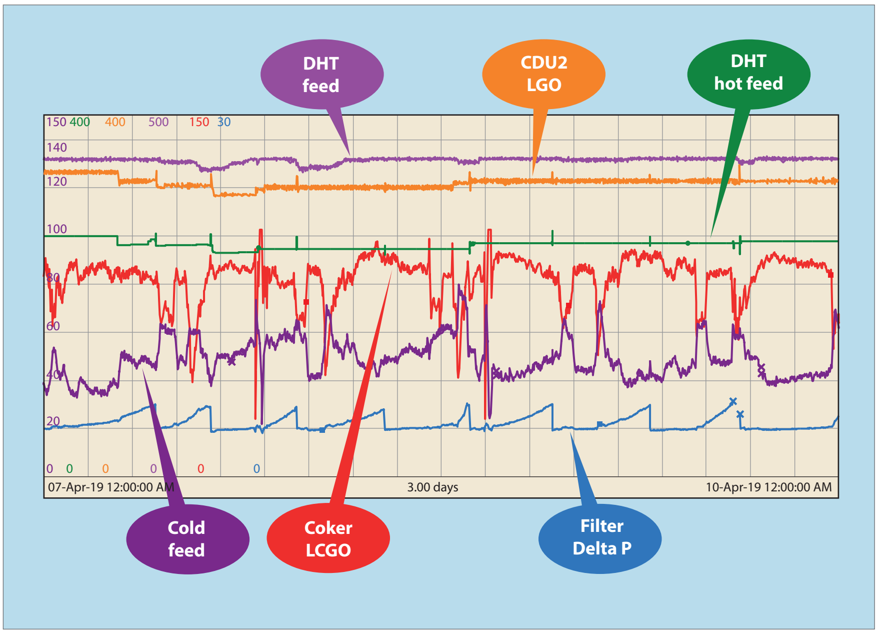

Figure 5a DHT feed filter three-day trend before APC

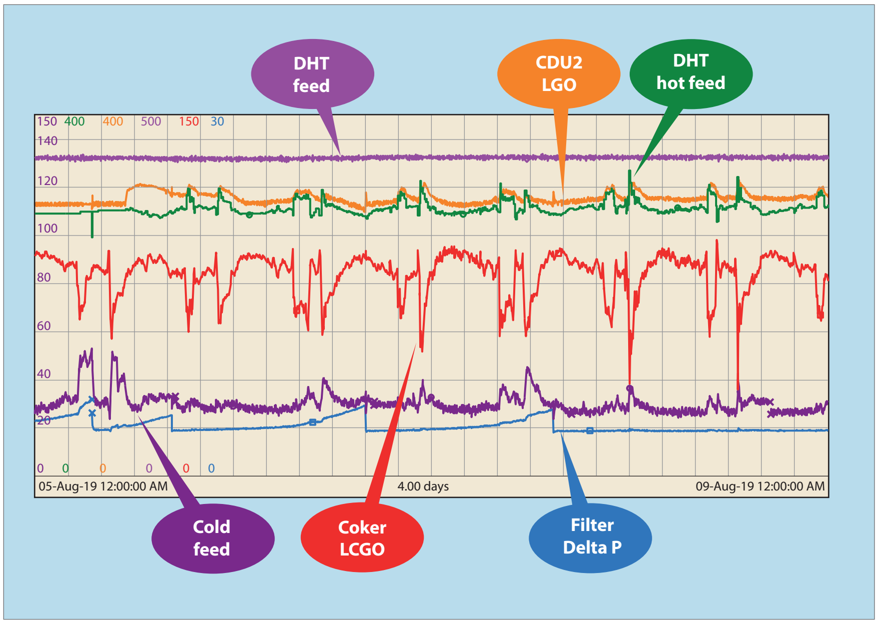

Figure 5b DHT feed filter three-day trend after APC

- Feed filter pressure difference (blue); abrupt drops in pressure difference indicate filter switches

Before APC, the DHT hot feed was manually set. Cold feed averaged at 50 m^3/h, sometimes going up to 65 m^3/h during LCGO disturbance. Filter switching frequency was 2-3 times a day, and sometimes the operator was forced to cut DHT feed (magenta trend in **Figure 5a**). A very different operation can be seen in **Figure 5b**. Under APC, filter switching frequency slowed down to once per day and DHT feed flow is steady. It is of interest to observe the response to coker drum switches. CDU2 APC tries, among many constraints and targets, to minimise DHT cold feed. When cold feed increases, due to drum switch disturbance, CDU2 APC responds by temporarily increasing LGO production and DHT hot feed. With APC, the average cold feed dropped to 30 m^3/h, with spikes up to 40 m^3/h.

Without APC, in addition to the nuisance of frequent filter switching, there was an average 3 m^3/h throughput reduction, valued as the difference between premium diesel and local diesel. Over a full year, even such a small reduction carries a penalty of several million dollars.

And during this time of CDU product yield manipulations, was the APC successfully controlling product qualities? **Figure 6** is a four-month trend of LGO 90% and 95% point inferences versus lab tests. During the initial period, May through mid-June, APC was off. Then from mid-June onwards, APC was active, and during that time LGO 95% point is stable, with minimal deviations from the 400°C target. In terms of inferential accuracy, there are certain laboratory outliers, though in general this is a high fidelity inference, tracking well against lab values.

Conclusion

We are proud of this project on several levels. One is the elimination of a major refinery headache. No official benefit is associated with 'headache' but those of us involved with refinery operation know that operator stress may result in incidents. Secondly, while cross unit optimisation is difficult, local unit optimisers do not always improve refinery operation. Dynamic global optimisation of the entire refinery is beyond the ability of current control technology, but manipulating one unit to alleviate constraints in another is indeed within our capability, and such opportunities are the biggest APC money makers. We estimate the benefits of just tying these two units together in APC, keeping DHT throughput high, not at the expense of reducing CDU middle distillate yields, at $10 million annually. That is on top of all other CDU APC control benefits.

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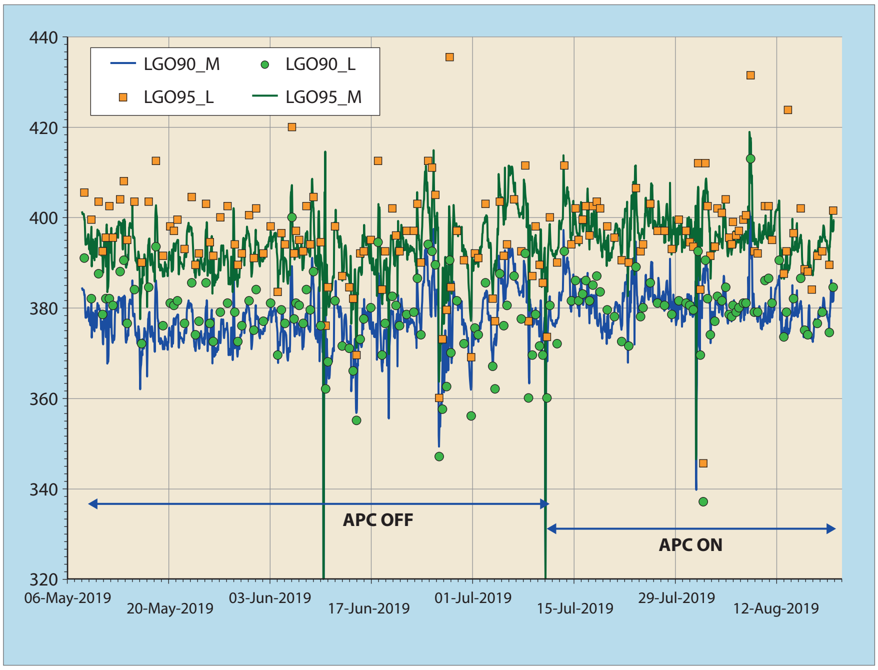

Figure 6 LGO 95% inference vs lab trend

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