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Part 1—What is advanced process control?

A stream of e-mail that followed my January and February editorials[1,2] has convinced me that an advanced process control (APC) tutorial would be beneficial.

First, a conceptual discussion: What does APC attempt to do and how does it make money? At the first level, APC aims to produce products at target qualities, while keeping the unit within constraints. Handling disturbances such as crude, coker drum and FCC feed switches, and ethylene cracker furnace starts and stops is no small feat. APC that can keep product qualities steady during these disturbances eliminates product downgrading and reduces the potential for incidents.

Moreover, this basic task is a prerequisite that must happen before we attempt further optimization. Optimization involves moving the unit up and down against constraints. APC must keep the product qualities constant during this self-inflicted disturbance, or else optimization becomes counter-productive. The warning that unit optimization is not to be started before the APC can handle quality control in the presence of disturbances cannot be overemphasized.

But product qualities, as well as certain important constraint variables, are not measured. If we are to push the unit against real constraints, we must calculate the unmeasured control variables inferentially. Unmeasured constraint variables are typically column tray loading, catalyst coking rate, etc. For product qualities, in the past it was common to rely on onstream analyzers for measuring product qualities. But analyzers, in addition to being expensive, require maintenance.

We used to have an unofficial standard of about two man-weeks per year per analyzer for maintenance. However, most refineries are no longer willing to dedicate that amount of labor. Analyzer reliability dropped to the point that it may be unsafe to use certain analyzers in closed loop.

APC level two. On the strength of level one, APC level two aims to maximize usefulness of the unit in question by maximizing throughput (or another key economic driver; but to simplify the discussion I will continue to refer to throughput), again while keeping the products at economical quality targets. Ignoring for a minute the dynamic difficulties of operating the unit, level two is easy to achieve.

APC would nudge the feed higher and higher until one of the unit constraints is met. Is that a big deal? After all, the operator can also maximize throughput to a pump limit or another constraint. Still, APC handles the dynamics of constraint pushing better than the average operator, and it can typically increase throughput by 1%–2% as compared to an average operator; more if the constraints are dynamically difficult to control.

APC level three. APC level three is trickier. There are usually enough degrees of freedom to move the unit in such a direction as to alleviate the active constraint. For example, consider the trade-off between reactor throughput and severity. We could reduce severity, lose some yield and increase throughput even more. In some cases, the economics of making such a move are straightforward and do not change with time. Then we can easily incorporate constraint-relieving logic into the application. In other cases, economics change from day to day, and the unit behavior is also not constant in time. Thus, third-level APC is only partially achievable. The degree to which it is achieved has to do not only with changes of economic directions, but also with the strength of application design and implementation.

With the development of fast computing and rigorous unit models came the notion that rigorous models can precisely estimate the effect of reducing reactor severity on the unit, determining whether severity should be decreased or increased. I would name this technology real-time rigorous optimization (RETRO) and stay away from commercial names. Initially, this seemed an excellent idea. Those of us enamored with chemical engineering models, myself included, thought that, while there are problems making this technology work, in the end it would be a reasonable way to optimize a unit.

This may still be correct in the remote future, but RETRO as it is used now has not been productive, and I have written papers and editorials advising people to hold off on RETRO.[3,4,5] There is no point repeating the discussion of the many problems, except to add that even, if one is optimistic that the problems are surmountable, there is still the question of do we want to spend 90% of the money and manpower resource to achieve the last 20% of benefits? The rest of this editorial ignores RETRO, because the way it is presently being implemented is not productive. HP

Part 2 next month will discuss the structure of modern APC applications and what APC actually does.

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