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Part 3—What is advanced process control?

Part 1 discussed what APC attempts to do and how it makes money. Part 2 discussed the structure of modern APC. This part discusses MVPC's small optimizer and the importance of inferential models.

Small approximate linear program optimizer. Today, we must accept that the MVPC by itself works on wide ranges and its main task is to keep the unit operating within an operating envelope. What gives MVPC the added value is a small optimizer (small approximate linear program, SALP) that determines which of the constraints are to be pushed against. SALP is an integral part of every MVPC. Its main function is to calculate manipulated variable steady-state values to narrow the control ranges on variables with genuine operating targets.

As opposed to the MVPC, which should act aggressively if limits are violated, SALP nudges the manipulated variables to their near-optimal position, thus achieving the operating targets without losing stability, albeit slowly. This permits the application to first meet the requirements of APC level one, and second, increase the throughput while satisfying the operating targets. SALP also attempts the APC level three constraint balancing: alleviate active constraints based on some rudimentary economic rules, making room for more feed, though that function is more problematic.

SALP is driven by a steady-state model, which uses process gains of the MVPC dynamic models plus prices set on MVs and CVs. On paper, SALP could be constantly updated with the economics of the day and then it would correctly optimize the unit, but that is not commonly done. Changing the performance function of SALP daily is too labor intensive. Further, for economical optimization to work correctly the unit behavior models must also be accurate, and linear empirical models do not come close to the accuracy needed to obtain detailed optimization. One might say that while there is no economical optimization, SALP sets priorities to balance and relieve certain constraints over others.

Does approximate constraint balancing make money? Reconsider our example of reducing reactor severity to alleviate throughput constraints and then pushing the throughput higher. If such a decision is valid all the time, or even seasonally, then approximate constraint balancing makes money. But if the validity of such a decision varies day to day, SALP should leave the severity decision to the operator. There are trade-offs in every unit that are more or less always valid. Thus, simplified constraint balancing can make money. Having said that, the APC engineer must always be there to check whether the unit is being pushed in a reasonable direction. It is all too easy to lose money by pushing APC in the wrong direction.

I keep referring to SALP as linear and that is not entirely true. Most products have quadratic programming (QP) ability. But since we do not usually update the economics, there is no incentive to add the QP complexity.

Inferential models. While MVPC and SALP are standard tools that can be made to work with good engineering, inferential models of unmeasured control variables are not standard and, hence, more problematic. High-fidelity inferential models are essential for success of APC because, as SALP attempts to push the unit against constraints, it is necessary for the operator to know that products are on spec, columns would not flood and catalyst will not deteriorate quickly. What is the point of pushing a reactor to high severity if that would cause premature catalyst deterioration?

Good operators have inferential knowledge, not in a mathematical form but as pattern recognition. APC, however, requires a mathematical form. Our industry, by and large, has made the mistake of replacing operator knowledge by regression models for the inferences. My February editorial[1] explained why that is not a good idea. I do not understand why industry has failed to address this important issue. After all, what is an inferential model? The patterns that operators try to maintain indicate that there are chemical engineering relations between measurements and product qualities. The patterns may be incomplete, meaning some key measurements are missing. In those cases, controlling the unit is quite difficult. As a part of developing the inferential models, one must identify those missing measurements to improve controllability.

People have accused me of being self-serving when speaking about the need for first-principles inferential models. That is not true, and I would not abuse my editorial position to say anything I do not believe in. I started dealing with inferential control problems many years ago for three reasons: personal, by necessity and commercial. The personal reason is love of chemical engineering models. I could and have used simulations and engineering models in a variety of applications not related to inferential modeling. The necessity reason showed up while working on APC applications; I had to come up with inferential solutions to make them work. The commercial reason: there is great need for good first-principles inferential models, and I have very little competition. That is still our situation. One might say that, by pointing out this need and even suggesting ways to achieve good inferential models, I am encouraging competition, rather than suppressing it.

Well-designed modern APC applications employ inferential models even where reliable analyzers exist. Inferential indications typically lead analyzer readings by one hour, and that is a significant dynamic control advantage. If MVPCs could take a cascade structure, it would have been ideal to set the analyzer as a primary controller and the inference as a secondary slave controller. But since that is not feasible, the accepted practice is to use the inference as the CV, whereas the analyzer is used to slowly update an inferential bias via a Smith predictor-like algorithm.

That is the end of this APC tutorial. To summarize, there are three main pieces in this puzzle: MVPC, SALP and inferential models. MVPC and SALP are packaged software, which may be imperfect but offers the advantage of a standard approach. Inferential models are not packaged software, and that makes inferential models the most crucial key component that could make or break a project.

Between the lines, I have tried to also discuss the task of the APC engineer. Given the loose ends of APC technology, it is not easy to accomplish a successful APC application. APC engineers must be thoroughly knowledgeable in the unit chemical engineering, operation and economics. He or she must stay with the application after commissioning, dedicating perhaps 30% of his or her time to each major application. Any application without attention would deteriorate rapidly. In that respect, the fourth piece of this puzzle is the human element and level of support given to working APC applications. **HP**

LITERATURE CITED

1 Friedman, Y. Z., "More about inferential control models," *Hydrocarbon Processing,* February 2005.

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