

## **Why coker APC applications are tough**

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I have just come back from ROG Horst refinery in Germany, where I helped commission a coker MVPC (multi-variable predictive control) application (see project info box). Commissioning brand new APC applications has always been a stressful job, because APC takes the unit into new territories that have never been experienced before, while pushing the unit to meet multiple constraints. When everything works well APC is wonderful, but I have yet to witness an application being commissioned without any problems.

Saying the same thing in a different way, to really make money on APC the application must be configured to

- Maximize feed to real constraints
- Balance the unit key handles to alleviate active constraints, permitting a further increase in feed and meeting even more constraints simultaneously
- Maximize the yield of valuable products to quality specifications (meeting more constraints)
- Handle typical unit disturbances

Upon commissioning, the application tries to work as intended, pushing the unit against several constraints, which is quite stressful both for operators and control engineers. The initial controller is unlikely to work perfectly, but it is still necessary to test it near real constraints to flush out the problems. Further, product qualities are now estimated by a brand new inferential model, which the operator is being asked to have faith in, while the unit is being pushed harder and harder.

On a coker there is the added complexity of semi-continuous operation, twice daily drum switches, and the unforgiving high temperature coking furnace environment, with the ever present possibility of instrument failures. If that is not enough, the matrix of control variable responses to manipulated variables is dense. Usually in refinery units each control variable is associated with one or sometimes two main manipulated variables, and process dynamic response matrices are fairly sparse, but in a coker each of the main manipulated variables affects many control variables and that is a challenge for the MVPC. Good control under such conditions requires high accuracy of the unit dynamic response models. In the absence of such accuracy constraint balancing cannot be achieved without constraint violation.

Having finally commissioned the coker application, I thought it would be useful to take stock and reiterate on what one should do, and not do, when commissioning a complex application. All of the suggestions below are obvious, though we control engineers are sometimes guilty of not following them vigorously, and that costs us dearly during commissioning.

1. Do not skimp on labour during the response model identification period  
Obtaining good dynamic response models is a desirable goal in any application. The more accurate the dynamic model – the easier it is to commission the application, and the better the control performance. With coker APC application

being a dense matrix, inaccurate models lead to instability. On another unit perhaps the control engineer would get away with slowing down the controller to deal with model inaccuracy, but on a coker, slowing down the application impedes its ability to move swiftly during drum switches. If that is not difficult enough, some models are nonlinear and require a linear transformation or other tricks to make sure that the controller “soft lands” on constraints, avoiding limit cycling.

Sometimes there are subtle changes in the unit, which change dynamic behaviour. For example we had a hard time with a simple pump-around temperature controller valve position constraint, only to realize later that the control valve bypass was partially open and that changed the control valve response.

2. And since no dynamic model will be always correct, a reasonable solution here is to have an intermediate region near (but inside) constraints where the control action is gentler.
3. Handling of minor constraints  
Do not insist that all unit constraints are incorporated as control variables and ranked high. That would sometimes make the tail (an insignificant constraint) wag the dog (reduce feed flow). We ended up employing two methods to avoid such scenarios: one – shed minor constraints when there is no convenient way to control them, the other – erase the dynamic models between feed flow and minor constraints to prevent a feed decrease. Those enhancements have significantly improved operator acceptance.
4. Handling of major constraints  
On the other hand the controller must respect all major constraints. Occasionally the application would reduce feed in response to constraints, making operators unhappy because they thought that a different action to alleviate the constraints would be more profitable. That boils down to training and setting constraint limits correctly. Before APC the operator would operate the unit to conservative targets, allowing small violations of those limits. For APC a limit on a major constraint is to be respected, and if constraint balancing is not possible it would pull down the feed. Operators must be trained to give the application as much freedom as possible, setting real control variable limits that are not be violated, and widening manipulated variable limits, to permit constraint balancing, and avoid feed reduction unless that is really the only way to keep the unit safe.
5. Agree on product economics  
With coker products going to downstream units, marginal product values are a matter of interpretation and there are often disagreements within the refinery about the relative values of coker naphtha versus distillates. Nevertheless it is necessary to agree on the economics in order to achieve a consistent control strategy. This strategy may not be fully correct, and we need then to give the operator additional handles for changing the yields, for example by setting product cutpoint or product rundown flow limits.

6. Nearly redundant control variables are difficult  
People make use of similar constraints for good reasons. For example certain column temperatures are used as control variables, first in order to back up inferential models and second – to ease the operator transition from relying on these simple indicators to the more sophisticated quality inferences. Such nearly redundant control variables can cause the dynamic matrix to be ill-conditioned, which in turn would result in limit cycling. In addition to ensuring good model conditioning for parallel models, following a short period of operator training it is best to widen the back-up variables limits to avoid competition between main and back-up variables.

7. Attention to detail

Following a coke drum switch, the coke is stripped by steam for about half an hour, and that significant flow of steam goes into the fractionator, altering the partial pressure and the inferential calculations. Later, the fractionator connection is shut off and stripping steam diverted to the blowdown system. Steam is also introduced to de-aerate and warm up a drum when it is empty and ready to go back into service, and at that time the steam is simply vented.

Our biggest inferential model problems had to do with the calculation of what part of the coke drum steam flows into the fractionator. The initial steam calculation in the inferential program mistakenly assumed that warm up steam also goes into the fractionator. Due to the calculated (but not real) change in partial pressure, inferential indicators would jump by several degrees and the MVPC response would disturb the column unnecessarily. That problem, that once discovered was trivial to solve, had hindered the commissioning of inferential models for months.

8. Operator training

While never to be overlooked, the importance of operator training is critical for the success of coker unit APC. Because of the dense response matrix, when the unit is pushed against several constraints the application moves to balance constraints in ways that operators (and engineers) do not immediately understand. The APC engineer often spends hours investigating controller actions that at first sight look incorrect, for example, why last night the controller took an action to change fresh feed temperature for no apparent reason, only to find out that the unit was so constrained that that move was the only way open for the controller to cope with ambient temperature change without reducing feed.

What about the operators who do not have tools or time to conduct APC control investigations? They have access to see the steady state situation that the controller is trying to achieve, but in a complex multi-variable environment such information does not always obviate controller actions.

Here is what Volker, who conducted the operator training had to say. *“For the coker operators this was first encounter with multivariable issues, and training without overwhelming them was a challenge. I found it best to conduct training using the sophisticated tools at our disposal: WebViewer, FOXBORO Bridge, etc, so that operators are forced to start using those tools. I have also used the opportunity to introduce the basic concepts of control, starting with a control loop, how*

*MVPC interacts with the DCS, and then going through MVPC concepts: MV, CV, DV, Inferential CVs. For operators who had prior MVPC exposure I would insist on at least a short refreshing course. My aim during training sessions is to teach skills in general and not to clarify a situation (for example why the controller is reducing fresh feed just now), in the hope that with time operators would figure out specific answers on their own.*

*In addition to the official training it is the duty of control engineers to spend time and to have time for the operators, even at the cost of delaying other work. To gain operator acceptance I must demonstrate not only skill but also interest. I would occasionally ask an operator why he had set a certain limit, and whether he was aware that that limit is now a throughput bottleneck. My ultimate goal is to have the operators take over and be responsible for setting correct limits. They are gradually getting the idea that APC releases them from tedious work, but now they must use the tool for the intended purpose: to optimize the unit operation.”*

9. Last but not least, there was one ingredient without which this project would have surely failed. The three persons involved in the project learned to trust each other. Decisions were made together, problems were solved in harmony, and no finger pointing ever took place. In spite of the challenging issues mentioned above, work was enjoyable and we have nothing but good memories left from the project.

### **Project info box**

Sean Goodhart of AMT was responsible for DMCplus implementation (configuration, tuning and commissioning), for coding the inferential model (in visual basic on Aspen IQ), and for system integration.

Zak Friedman of Petrocontrol has supplied inferential models and was also a client representative.

Volker Haseloff of ROG coordinated the project locally, participated in every technical activity, trained operators, and will be responsible to keep the application working. ROG is a joint venture of BP and PDVSA.