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APC designs for minimum maintenance—Part 2

My last month's editorial proposed that since our advanced process control (APC) applications are by and large under-maintained, these applications should be designed in the simplest possible way. The design rule discussed was: Do not clutter the control matrix. Associate each control variable, *CV*, preferably with one, hopefully no more than two, manipulated variables (*MVs*). That was accompanied by a distillation column example (Fig. 1), which this editorial will continue to use proposing additional rules.

Design rule 2. Avoid nearly redundant *CVs*. Our example last month showed a 3 *MV* by 3 *CV* design as follows:

- Tray six temperature, *MV*1
- Reboiler steam, *MV*2
- Column pressure, *MV*3
- Top product inference, *CV*1
- Reflux valve position, *CV*2
- Reboil ratio, *CV*3.

But such a design with only one inferential model goes almost against the grain in our industry. Many APC practitioners would consider several additional *CVs* for our distillation example:

- Pressure-compensated top temperature, *CV*4
- Pressure-compensated tray 25 temperature, *CV*5
- Pressure-compensated bottom temperature, *CV*6
- Bottom purity inference, *CV*7.

The rationale for these *CVs* has to do with lack of trust in the inference models, and setting up redundant simple inferences to protect the application from failure of the main inference model. That is the same kind of fear that would drive the operator to set a tray six temperature, *MV*1, limit, except redundant *CVs* damage the APC performance more than *MV* limiting. A degree of freedom analysis reveals that at most two inference *CV* targets can be met on this column, one related to the top product and the other to the bottom product purity. But the multivariable predictive controller (MVPC) has no such knowledge; it works by inverting the dynamic response matrix, and since there are always small differences among models, the MVPC can be misled into finding a "solution" that would meet three inferential model targets. Because of the almost colineal *CVs*, instead of a real set of conditions, ill-conditioned MVPCs tend to push the unit to extremes, for example minimum pressure and maximum reflux, or vice versa. The column in Fig. 1 does not normally flood and hence, no flooding detection *CV* is specified, but the erroneous solution might drive the column into flooding. Now the operator has another reason to limit *MVs*—to avoid a minimum-pressure–maximum-reflux solution.

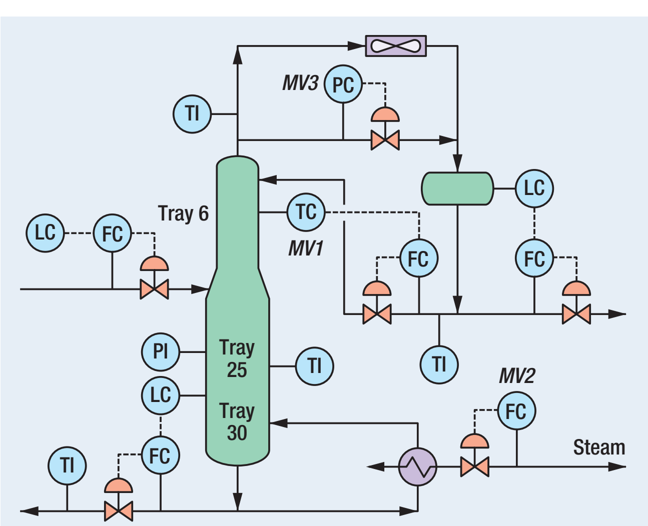

FIG. 1 A distillation column candidate for APC.

To reiterate, when an APC application is operated correctly, redundant inferences would have wide ranges and would not usually come into play. But in an unsupervised application, due to operator lack of confidence, the redundant inference *CV* ranges could be narrowed enough to bring about strange infeasible MVPC solutions. At that point the operator would lose the remaining confidence and turn off the application indefinitely.

Design rule 3. Restructure necessary near colineal *CVs* to avoid ill-conditioning. In the distillation example it actually is feasible to control both top and bottom purities. Can we avoid near colineal *CVs* in that case? Our design rule 2 above simplified the problem by setting a reboil ratio, *CV*3, considering that if the top product is on specification, reasonable loading of the stripping section ensures that bottom product purity is also acceptable. That would be my preferred solution for dealing with inadequate APC engineering attention.

Although there is another solution: Set up an inference *CV*3 called fractionation using a combination of top and bottom inferences as follows:

$$CV3 = \text{fractionation} = \text{top impurity} + \text{bottom impurity}$$

We have thus created a *CV*3 that is not parallel but rather orthogonal to *CV*1 by using process engineering knowledge. Associate *CV*3 with reboiler steam, *MV*2, and tune it to move only very slowly.

Note that we have associated *MV*2 also with reflux valve position, *CV*2. If the operator demands more fractionation than this column can deliver the MVPC should be configured to ignore *CV*3. **HP**

The author is a principal consultant in advanced process control and online optimization with Petrocontrol. He specializes in the use of first-principles models for inferential process control and has developed a number of distillation and reactor models. Dr. Friedman's experience spans over 30 years in the hydrocarbon industry, working with Exxon Research and Engineering, KBC Advanced Technology and since 1992 with Petrocontrol. He holds a BS degree from the Israel Institute of Technology (Technion) and a PhD degree from Purdue University.