Originally appeared in:
August 2011, pgs 87-90.
Used with permission.
HYDROCARBON PROCESSING®

Pre-engineered solutions drive down advanced control costs

Process control can improve quality and operating efficiency

P. SHARPE and G. HAWKINS, Emerson Process Management, Austin, Texas

Most companies today have honed their process control staff down to the minimum required to maintain a control system that can safely operate the process units. This leaves little time for the internal development of strategic applications that can improve process and safety performance. While some refineries and major petrochemical sites are able to justify dedicated teams of engineers to take care of advanced process control (APC) systems, many processing sites are still dependent on outside help for implementation, revamps and ongoing maintenance of APC systems. As a result, traditional APC initiatives have been stalled by the organization's lack of capacity to identify, fund, staff and maintain advanced automation investments, even though the cost can almost always be justified.

Most process control managers recognize that there are opportunities to use APC to improve quality and operating efficiency, but feel constrained by economic and resource realities. Pre-engineered, packaged solutions provide a unique way to kick-start implementation of these applications for the most common process units found in industry. Reusable, built-for-purpose applications drive costs out of the design, implementation and maintenance efforts, much as pre-fabricated housing takes costs out of building construction. These are simple, straightforward applications that can be put online in a matter of a few weeks, once all the basic instrumentation and control issues have been resolved.

Two packaged applications (one for distillation columns and one for boilers) are discussed in this article. What the discussion will illustrate is that pre-engineered APC applications can be utilized to obtain maximum benefit at a fraction of the historical cost of traditional APC projects.

Benefits of APC. Many companies today have implemented initiatives to reduce energy consumption. For most plants, energy is the second largest operating cost behind feedstock.[1] And because improving energy efficiency is the best way to reduce greenhouse gas emissions, environmental considerations are driving a refreshed look at energy conservation projects in the developed countries. According to the US Department of Energy, there are more than 40,000 distillation columns in the US alone that consume roughly 19% of all energy used in the processing industries and 6% of the total US energy consumption.[2]

It turns out that distillation columns are a classical application of advanced control, in which long time constants, interacting control loops and multiple equipment constraints can cause operators to run more conservatively than the optimum. In the case of distillation, this usually means: using more energy than necessary; reducing product recovery; and/or higher product quality "giveaway."

Incremental energy usage skyrockets for high-purity columns the closer they get to 100%. A 2008 case study on a styrene column shows that the incremental steam cost to increase the purity from 99.6% to 99.7% represented more than 13% of the total energy used by the column, as shown in Fig. 1. That's roughly $600,000 annually in unnecessary expense.[3] Yet while over-purification of distillation column products can be expensive, both in terms of energy and product recovery, it is often not readily visible to the operators. Reducing the energy consumed per unit of distilled product is imperative for producers to operate the most efficient plants.

While not every column requires operating to high-purity

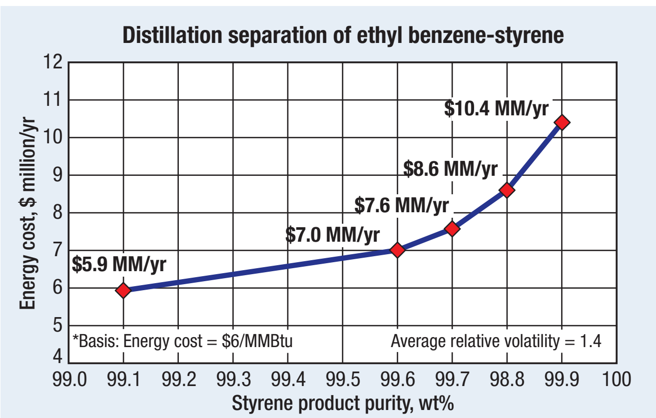

FIG. 1 Energy cost vs. product purity in a styrene column.[3]

specifications, the principal is the same. The closer you can operate to the product specification (without violating the limits), the more profitable the operation. APC can improve column operations because it continuously predicts how the control and constraint variables will respond in the future and makes multiple adjustments every minute to keep the system optimized. This, of course, is not a task that even the most experienced operators can feasibly accomplish in their heads.

APC can also help boiler management. According to a study prepared for Oak Ridge National Laboratory, there are almost 163,000 industrial boilers in the US larger than 10 million Btu/hr that consume almost 37% of all energy (excluding electricity) used by industrial facilities.[4] Optimal boiler usage can slash the fuel bill of any industrial plant. Operating available equipment at maximum efficiency, shifting loads to more efficient producers, maximizing use of waste fuels and optimizing the site's steam headers can be worth millions annually, often representing more than 8% of the site's fuel purchases.[5]

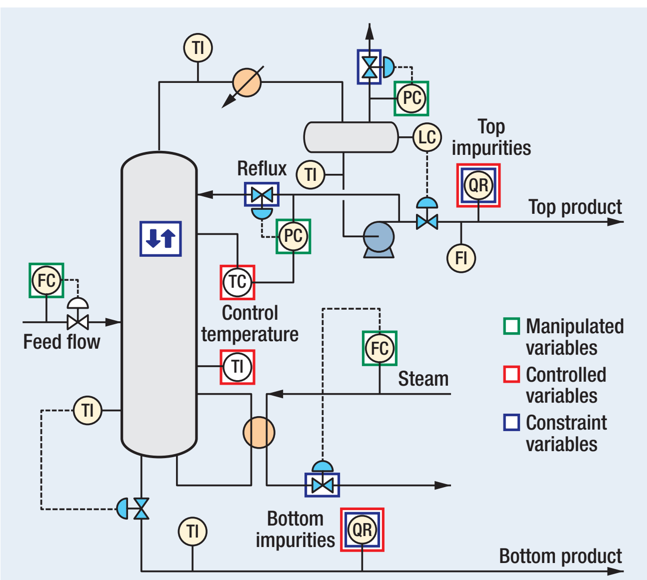

FIG. 2 Advanced control of distillation columns like this one can be generalized from one site to the next.

Pre-engineered solutions. Distillation columns, boilers, fired heaters, cracking furnaces, fractionators and blenders are examples of very common unit operations that lend themselves to a more standardized, packaged approach. While each plant will be different in its layout and design, the fundamentals of the processes, typical measurements and control objectives will be similar from one site to the next. A typical two-product distillation column is shown in Fig. 2.

For these columns, one can generalize the column operating objectives as:

- Maintain overhead and bottoms qualities within target range
- Maximize yield of most valuable product
- Minimize energy usage
- Minimize column pressure (to improve relative volatility)
- Operate within all equipment and process limits.

As shown in Fig. 2, these distillation columns may have up to four manipulated variables, two to four controlled variables, and a common set of constraints such as valve and column hydraulic limits. Most columns will have the key measured variables shown in Fig. 2 that are inputs to a standard set of calculations such as pressure-compensated temperatures, internal vapor and liquid traffic, reboiler and condenser duties, and key performance indices (KPIs) like material balance error or cost per unit product.

Similarly, boilers also represent common unit operations that lend themselves well to pre-engineered solutions. Common boiler control objectives include:

- Generate the target steam demand
- Minimize excess combustion air
- Maximize use of lowest cost fuel
- Control steam-drum level
- Maintain steam supply pressure
- Operate safely within all operational and equipment limits.

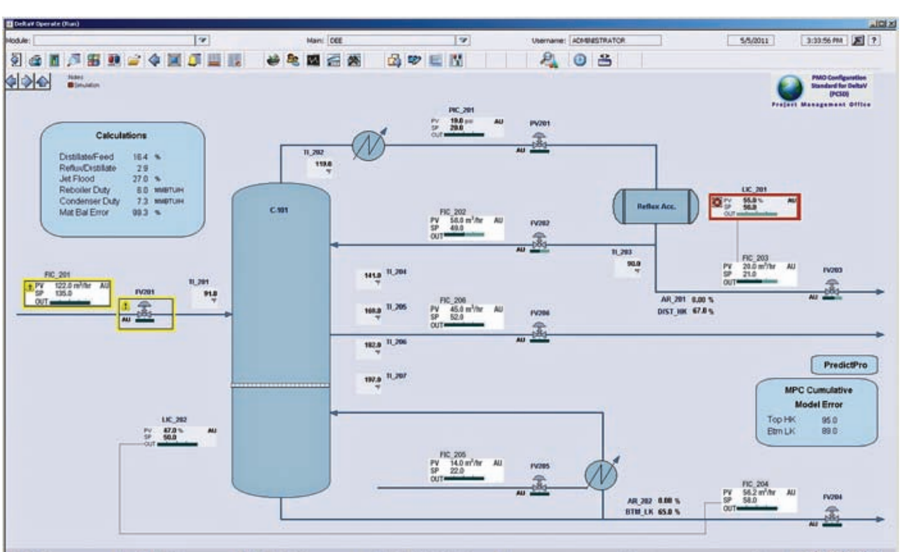

FIG. 3 The column model predictive control strategy, in terms of manipulated, control and constraint variables, will be similar from one column to the next and is easily edited.

In general, the boiler advanced control strategy manipulates fuel, combustion air and boiler feedwater to achieve these objectives. These units also have a typical set of KPI calculations used to monitor the performance, including boiler efficiency, heat rate, steam cost and emissions.

Candidates for pre-engineering. Successful APC projects use a holistic approach that starts with a review of the regulatory control layer and its dynamic performance. As part of any APC project, it is important to address issues with control valves, loop tuning and process measurements to obtain stable, responsive performance in all key control loops. Experience has shown that significant performance and reliability improvements can be obtained just through resolving issues at the regulatory control layer. An APC project is often the driver for fixing problems that may have existed for years.

Instrumentation. Most process plants were designed and built with the minimum amount of instrumentation—just what was essential to operate the unit safely. However, improving reliability and energy efficiency often requires additional process measurements. For example, one would expect at least those measurements indicated in Fig. 2 for a typical distillation column. If any of these monitoring points are not available, they can be added wirelessly. In mature operating units that have been running for several years or even decades, instrument engineers may have already used much of the original spare wiring as instruments were added or replaced or as existing wiring failed. Current wireless measurement devices offer an alternative that greatly minimizes engineering, installation and commissioning costs for new process measurements.

Calculations and control functions. Given a set of typical inputs, it is possible to standardize calculations and control functions so that project teams do not end up re-engineering commonly-used functionality on every project. This standardization moves dramatically away from the old paradigm, in which new projects were based on the functional designs from the last project, to a productized approach with pre-engineered and tested function libraries, documentation and software support. On a modern control system, the user simply wires the inputs using drag-and-drop actions to the distillation block and all the standard calculations are performed automatically, with no need for further engineering.

In addition to the standardized calculations, advanced control tools needed to optimize the column can be included and predefined for a typical column. While the advanced control configuration for a particular column will need to be adjusted based on the regulatory controls, the column model predictive control (MPC) strategy, in terms of manipulated, control and constraint variables, will be similar from one column to the next and is easily edited, as shown in Fig. 4.

An important note with respect to the APC scope: There are those who suggest that one must implement a single, large MPC strategy that spans an entire process unit or distillation train. In practice, we have found many successful applications that break the problem down into smaller, easier-to-understand components. Implementing one MPC strategy per column simplifies step testing, model identification and troubleshooting, and improves long-term utilization. Since a single column controller is easier for an operator to understand, such arrangements tend to have higher online times. When required, MPC outputs can be easily used as disturbances or cascaded to secondary MPC controllers to accommodate interactions and constraints that cross column boundaries. The approach of networked MPC controllers is also an ideal way to handle site-wide energy management systems, including automatic shedding strategies for steam-limited operations.

Configuration tools. With a standard package, the configuration effort can also be automated somewhat with a set of tools that performs a complete system-wide search-and-replace for all the main elements like tag names and equipment IDs. These tools can be populated with standard descriptive tag names (used by the base module) and descriptions that can be edited by the user for that particular instance.

User interface. Every site will have its own specific graphics standards that dictate the color scheme and the look and feel of the process graphics. On the other hand, graphics and templates that have been field-tested and enhanced across many projects make a great starting point for customizing to a site's requirements. And the standard user interface comes with a user manual already completed. Graphical elements provided with a standard solution can make use of the latest technology and human-centered design (HCD) concepts to potentially improve

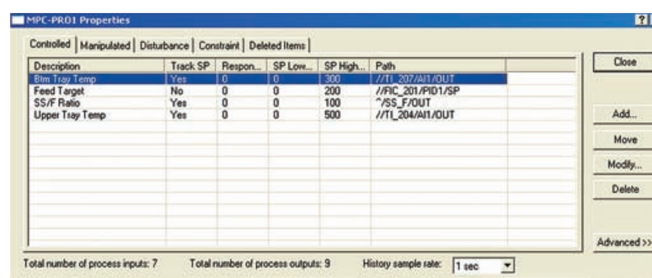

FIG. 4 Embedded MPC configuration can be easily edited to accommodate the specific project needs.

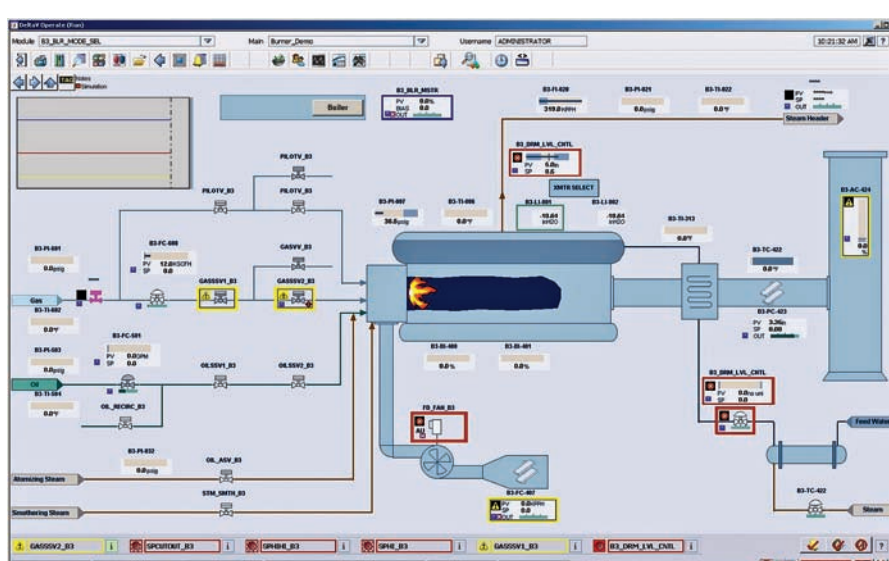

FIG. 5 Typical HCD boiler display.

operator effectiveness. HCD is an international standard (*ISO 9241-210:2010, Ergonomics of human-system interaction—Part 21*) that goes far beyond just screen designs to focus on the most common user tasks, making their access more intuitive and easy. One example of this would be minimizing the number of clicks required to get to the most commonly used functions. The latest operator graphic standards suggest using bold colors only when necessary to draw the operator's attention to something abnormal.

A typical boiler display is shown in Fig. 5. In this example, an operator can quickly see which parameters on the screen are not in their normal state.

Documentation. While project documentation will always require some level of customization, using standard applications reduces the documentation effort to more of a "cut-and-paste" exercise. Reference documentation for the calculations and control logic can be done once. User documentation can be leveraged across multiple projects.

Maintenance and support. Using standard, pre-engineered solutions rather than custom, "one-off" projects allows the vendor to offer a more complete support service. Now there are multiple resources besides the individual who performed the installation to help with any troubleshooting, support and upgrades. Support help line staff can direct technical calls to resources that are knowledgeable about that application.

Savings. How much can you save using pre-engineered solutions? That depends on your basis for comparison. Compared to doing nothing, the savings can be substantial. In one case, a distillation application was implemented for a Midwest US refiner in a total of two weeks and it paid for itself in less than two months. At a site in Texas, a chemicals manufacturer claimed steam reductions and product-recovery savings worth more than $700,000 annually for the first application on its high-purity distillation train. This project was also configured and implemented in only two weeks onsite. While company names have been withheld at their request, the savings are real.

Similar savings for implementing advanced boiler control applications have been experienced in powerhouses across many industries. For example, Monsanto estimates that it saved more than 8% of the natural gas used in its Luling, Louisiana, production facility by maximizing usage of a hydrogen-rich waste stream as boiler fuel.[5]

Compared to the traditional methods, where APC is implemented in a separate supervisory computer connected to the regulatory control system using OPC, embedded tools essentially eliminate the need for extra computer hardware, communications and databases. Pre-engineered solutions reduce the initial engineering cost by as much as 30% and provide a platform that can be supported across multiple installations.

For process control managers with APC as part of their business objectives, opportunities abound for small, dedicated MPC controllers that don't require a lot of effort to implement and maintain. Pre-engineered, built-for-purpose APC solutions lead to quicker installation, better long-term maintenance and higher onstream factors.

Current modern control systems have capabilities that were unimaginable in the past. These systems are truly much more than a DCS. Built-in APC tools provide control engineers with additional algorithms to solve tough control problems. No doubt, there are certainly many opportunities where a large-scale, multi-unit, supervisory MPC system (and the team to keep it running) makes sense. However, there is a whole class of control problems in which a small, dedicated MPC algorithm running in a high-speed, redundant controller environment can have a huge impact at a much lower cost. **HP**

LITERATURE CITED

1. White, D., "Trading silicon for carbon: How to reduce energy usage through automation," *Hydrocarbon Processing* June, 2010, pp. 61–70.
2. "Distillation column modeling tools," Office of Industrial Technology: Energy Efficiency and Renewable Energy, US Department of Energy, Washington, DC, September 2001.
3. Humphrey, J. L., F. Seibert, C. Lewis, and J. Farone, "Smart distillation prevents problems before they happen," AIChE Spring Meeting, New Orleans, Louisiana, April 2008.
4. Energy and Environmental Analysis, Inc.,"Characterization of the US industrial commercial boiler population," submitted to Oak Ridge National Laboratory, May 2005.
5. Henderson, J., "Waste not, want not: Optimized combustion of hydrogen and natural gas," Emerson Exchange, September 2009.

Pete Sharpe is currently the director of industry solution application development for Emerson Process Management. He holds a BS degree in chemical engineering from the University of Colorado and an MBA degree from the University of Houston. He has over 33 years of experience in the process control industry, in both technical and management roles, specializing in advanced process control. He has helped refiners, petrochemical manufacturers, utilities and polymer plants design, justify and implement major automation projects and control system upgrades. He has authored or co-authored more than 25 technical papers, and holds two patents on abnormal situation prevention techniques.

Gary Hawkins is a consultant within the PlantWeb global refining industry group of Emerson Process Management. Before Emerson, Mr. Hawkins worked 30+ years for a process technology licensor as a process control specialist, including field startup work, process engineering and technical services. He is active with the API Refining and Equipment Standards Committee and has a BS degree in chemical engineering from the University of Illinois.