Energy Management vs. Spot Energy Reduction Projects

In today’s manufacturing environment, there is an urgency to increase operating efficiencies, and to do it quickly. One area of improvement that can produce immediate results is reducing energy consumption. It’s good for the environment and it’s good for the bottom line. “Energy management,” therefore, has become a common best practice, but there is more there than meets the eye. Typically it implies rigorously modeling all or a major portion of the plant, coupled with the use of real-time optimization technology. While this approach has been used successfully, there are other simpler, faster options for reducing energy consumption in a manufacturing plant.

For example, advanced process control (APC) technology, which has been used to increase unit capacity or yield of the plant’s most valuable products, has also been successfully applied to produce energy savings in manufacturing facilities for the last two decades or more. This article will present some of the energy savings benefits routinely produced by implementing APC and show how applying these best practices can be quite lucrative at today’s energy prices.

APC Energy Reduction Benefits from a Historical Perspective

When APC was really beginning to hit its stride in the late ‘80s and early ‘90s, the financial benefits of energy savings were typically small when compared to unit capacity or product yield increases. For instance, the total US dollar benefit for an APC project applied to an oil refining unit was typically in the $800,000 to $1,500,000 per year range. Of that total, the savings on energy averaged $100,000 to $200,000. In contrast, recent APC projects have yielded savings of $400,000 to $900,000 in reboiler steam energy when applied to just a couple of refinery distillation towers.

The technology hasn’t changed much over the years, but what has changed is the cost of energy. A review of United States Department of Energy documents (Figure 1) shows that the price of natural gas has increased from about $4.5/MSCF in 1988 to about $13.0/MSCF in 2006. If this cost was applied to a boiler with 80 percent efficiency, the cost of 150 psig steam has increased from approximately $6/Mlb of steam to $17.5/Klb of steam. Similarly, the price of refinery fuel products has approximately quadrupled from 1991 until 2007. These increases account for most of the observed increase in energy-related benefits from APC applications. More recently, energy prices have tumbled back to the levels of 10 years ago, as shown in Figure 2. For the purposes of this article, the dollar value of energy savings will be presented both in terms of peak energy
prices (Natural Gas: $13/MMBTU; Steam: $15/Mlb) and a more average value for the early 2000s (Natural Gas: $8/MMBTU; Steam: $10/Mlb).
Mechanics of APC Energy Savings

In a nutshell, APC produces benefits by pushing constraints and performing more consistently and accurately than an operator can acting alone. A very common objective of APC applications is to lower the average pressure of a unit operation, which will often yield lower energy requirements. APC applications also commonly reduce operator conservatism, some examples of which include: 1) Stacking flue gas O₂ content higher than necessary for safe operation and enforcement of environmental regulations; 2) Over-refluxing a distillation tower to ensure that the overhead liquid product specification for impurities is always achieved; 3) Avoiding high-temperature constraints for reactor operations, resulting in lower conversion or yield levels. Items 1 and 2 above will always result in energy savings. Item 3 will result in energy saving too, if the increase in reactor performance results in less feed or recycle feed processed.

Here are a few case studies that illustrate some of the above situations and the energy-related benefits they produced.

Distillation Towers

The first case study is the application of APC to a fluid catalytic cracker (FCC) gas plant debutanizer tower in an oil refinery. The heating medium for the tower reboiler was 550 psig steam. The objective of the APC was to maintain the bottom gasoline product Reid Vapor Pressure (RVP) specification and overhead butane product C₅ content specification, while also minimizing energy consumption. The APC was put into service in mid-November and completed by early December. Figure 3 shows the key operating data during a three-month period. APC lowered the tower pressure and overhead reflux rate (top two trend lines), and due to the lower tower pressure, also reduced the temperature of the tower in order to hold the same product compositions. The bottom two trend lines show the resulting reboiler steam reduction and how this reduced the tower temperature by about nine degrees Fahrenheit. The average reduction in steam rate was about 13,000 lb/hr.

Using steam prices reported above, and allowing for 10 percent down time due to unit or APC issues, the yearly benefit for this steam reduction was about $1,540,000/year at peak prices or ($1,020,000/year at average prices). Since this reduction was achieved during the winter months (and a lesser reduction would be achieved during warmer months), half of this benefit is probably more realistic. However, $770,000 per year at peak prices ($513,000/year at average) is still a very attractive benefit.
In another case of distillation towers in a crude unit gas plant, rather than an FCC, reboiler steam reductions were achieved in another debutanizer tower and a gasoline splitter tower. For this project, a post audit was conducted by Invensys and the customer. Table 1 shows some of the key operating data outlined in the report. By applying the peak and average steam prices, the resulting yearly energy savings for this portion of the APC project was about $1,090,000 peak ($725,300 average).

<table>
<thead>
<tr>
<th></th>
<th>Before APC</th>
<th>After APC</th>
<th>Aft - Bef Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debutanizer Reboiler Steam (MLb/Hr)</td>
<td>20.3</td>
<td>14.4</td>
<td>-5.9</td>
</tr>
<tr>
<td>Naphtha Splitter Pressure (PSIG)</td>
<td>31.4</td>
<td>24.7</td>
<td>-6.7</td>
</tr>
<tr>
<td>Naphtha Splitter Reboiler Steam (MLb/Hr)</td>
<td>13.2</td>
<td>10.0</td>
<td>-3.3</td>
</tr>
</tbody>
</table>

These two examples show how lucrative energy savings can be obtained from typical APC applications. Even though APC has been applied to many distillation towers, additional energy savings can be achieved from these applications. The focus of these projects is typically on achieving the product specifications and shifting product yields toward more valuable products. Often there is not enough attention given to reducing the
tower pressure to the fullest extent, which would create additional energy savings opportunities

When energy savings are available on a distillation tower, the tower should be pushed to an absolute limit of overhead condensing capacity, tower flooding limit or pumping limit (valve opening). There are many existing distillation APC applications where a quick revamp to enhance the pressure minimization function would produce additional and significant energy savings.

**FCC Reactor/Regenerator**

Refinery FCC reactor/regenerators are another good example of where energy savings are commonly achieved. In FCC regenerators, a large amount of coke must be combusted from the catalyst that is continuously circulating between the reactor and the regenerator vessels. A correspondingly large amount of air must be injected into the regenerator vessel, which is commonly under 10 to 15 psig of pressure. The blower used to inject this air consumes a substantial amount of energy. For full-burn regenerators, the operator decides how much air to charge to the regenerator, using an online flue-gas O₂ analyzer. The objective of the APC control then is to reduce both the air flow and the regenerator pressure, while maintaining optimal coke combustion and stable catalyst circulation.

The following project results are from a recent FCC APC project. This FCC unit employed a full-burn regenerator design, and a post audit was conducted. Figure 4 shows the flue gas O₂ data for a one-year period before APC and a one-year period after APC. The 40 percent reduction of average O₂ levels is an example of how APC can reduce operator conservatism. The APC simply used less air to run the unit. The resulting reduction in 600 psig air blower turbine steam was 6,280 lb/hr. Again, assuming a 90 percent availability of the process and the APC, the resulting yearly dollar benefit was about $742,700 peak ($495,100 average).
Figure 4

Typically, regenerator pressure reduction is also an example of removing operator conservatism. In order for catalyst circulation to be maintained, a minimum amount of delta pressure between the reactor and regenerator vessels must be assured. Operators will typically stay above this delta pressure minimum, but APC pushes much closer to the actual minimum. It is worth noting that in this particular project, the valves used to control the regenerator pressure were not yet automated and therefore the APC could not manipulate the regenerator pressure, as would generally occur. If this manipulated variable had been available, the benefits achieved would have been significantly higher.

Associated FCC gas plant energy benefits were also achieved during this project -- about $600,000 peak ($400,000 average). The resulting total yearly energy related benefit was $1,342,700 peak ($895,100 average) for the overall APC project.

Conclusions

Energy savings can be obtained from many different APC applications. Basically, almost any unit where steam or fuel is being consumed is a candidate for energy savings via APC technology.

The process and control engineering communities have come to accept that APC projects produce lucrative charge rate maximization and product yield benefits when used to
enhance appropriate operating scenarios, however not to be overlooked is what APC solutions can do for producing energy savings.

The more comprehensive plant-wide “energy management” rigorous modeling approach certainly has its place as well, but APC projects are low-cost and fast-track in comparison, and savings can be realized in only one to two months. APC has always been a smart investment to make, even more so now than twenty years ago. With today’s energy prices, plant managers and executives should examine whether their APC applications are helping them save as much as they can.

# # #

About the author:

Paul Kesseler has been with Invensys Operations Management as an APC Consulting Application Engineer for ten years. Prior to this position, he worked at Setpoint/Aspen Technology implementing multivariable model predictive control technology in a wide variety of process units. He has been implementing advanced control applications for the past 23 years. He holds a BS degree in Chemical Engineering from Texas Tech University. Prior to his APC experience he was a process design engineer in the engineering and construction industry.