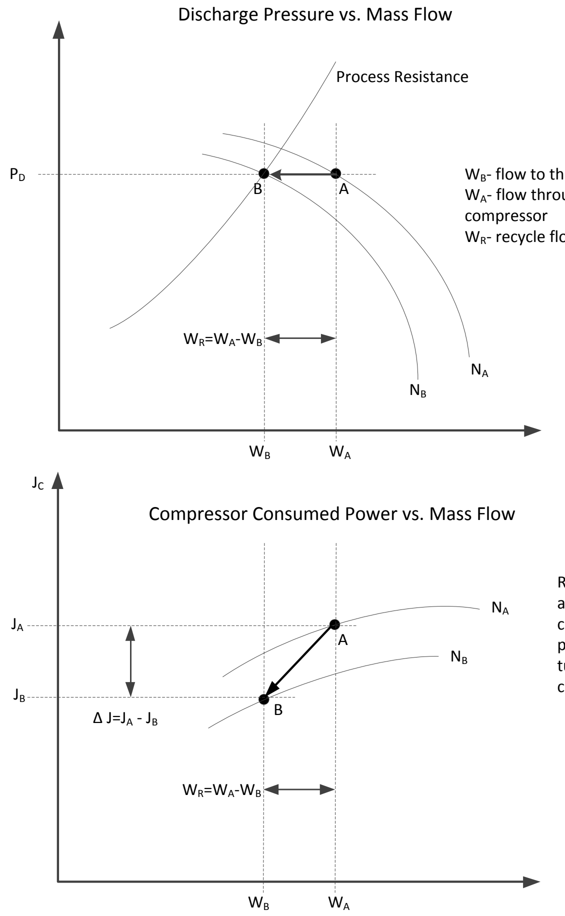
Expertise in Turbomachinery Controls

WHITEPAPER

Optimizing turbomachinery energy savings with control technologies



Reducing or eliminating recycle flow and subsequent reduction in compressor speed results in operating point moving from A to B, which in turn translates into reduced steam consumption.

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Virtually every plant manager in hydrocarbon processing, power-generation, and industrial facilities can relate to the need to optimize energy consumption. Opportunities to reduce unnecessary cost exist in various areas of production and operation, driven by the availability of new technologies and a need to improve the economic bottom line of the company.

Improvements in plant data capture and storage, mostly driven by advances in process historian and plant optimization technologies, allow us to shine a spotlight on areas of potential energy savings and take action with results that were unachievable until recent times. The past two decades have witnessed the adoption of process optimization technologies, which delivered handsomely in terms of cost reduction and improved throughput. The next frontier in plant optimization is in obtaining more operational effectiveness from critical turbo machinery, so that a plant can achieve maximum energy savings from both process and asset performance.

One area where significant improvements are now being demonstrated centers around the operation of compressor, turbine and motor control systems. Control systems technology can offer reliable information that energy savings improvements can be safely predicted and even guaranteed in several scenarios.

In order to translate this concept into reality, our team implemented a five step methodology spanning assessment through successful commissioning and operation of the plant. This approach has highlighted the following areas as the most common optimization opportunities in the hydrocarbon process industry:

- Decrease or elimination of recirculation and throttling of compressed gas
- Shorter startups and shutdowns
- Increased overall precision of control functions

Specifically, our research and experience has highlighted, often in repeated circumstances, the following findings:

Reduction in recycle rates

Surge protection margins may be set too conservatively due to inadequate design and functionality of the antisurge control system. As a result, the unit's power consumption may exceed process demand due to the excessive recycle flow. In such cases, the approach is to evaluate the existing system and provide recommendations as to the possible improvements which can include:

- Modifying the recycle valve for improved performance by updating the actuation, changing flow capacity, and/or relocation of the valve
- Modifying and/or adding instrumentation that provide measurements into the antisurge control system for improved antisurge control
- Changing antisurge control strategies in order to have more robust algorithms that will increase the compressor's operating envelope by having tighter control margins and integrated control

Automating capacity control

While most control systems were originally designed for automatic control, some are still operated in manual control by plant operators. One of the most common reasons for manual operation is the poor behavior of the speed governor. Older hydraulic and mechanical governors are often unable to match a varying set point without significant overshoot and/or undershoot. This frequently leads to a process upset or a trip. Consequently, operating personnel may run the unit at higher constant speeds and adjust capacity via recycling. In this case the savings will come both from the reduction in operating speed, as well as elimination of recycle. An evaluation of the speed governor design will determine what type of governor retrofit is required in order to accommodate automatic capacity control.

For units driven by constant speed electric motor, a throttling valve is often needed to modulate capacity. Many older systems may have poor performing throttling valves which are being operated in manual resulting in capacity control via recycle. Identifying ways to improve the throttling valve's performance will often lead to it being fully functional under automatic control. However there are some cases where replacing the entire valve may be necessary.

Another reason for manual operation is to avoid exceeding process or mechanical constraints due to an inadequately designed control system. A review of the existing control system and the system constraints will lead to identifying where and how limiting control should be implemented in order to have reliable automatic control within the boundary constraints of the system. Often, the operating boundary of the compressor can be increased when proper integration of capacity, antisurge and limit control is implemented.

Figure 1 shows an example of the power savings achieved by reducing recycle and lowering speed. Initially the compressor operates at point A, with flow equal to WA. However the process requires the flow to be equal to WB at discharge pressure PD. However, due to various reasons, such as poor governor performance and unreliable antisurge control, the compressor operates with recycle flow equal to WR. Using the compressor performance data, the savings in the consumed power can be estimated from the elimination of recycle flow and subsequent reduction in compressor speed. The reduction in the consumed power, Δ J, may be translated into reduction in steam consumption using turbine performance data and then into the reduction of operating costs. The calculations for multi-section machines may be more complex as performance changes need to be calculated for each section due to the effect the sections have on each other's inlet and outlet conditions.

Rotation frequency control improvement

Rotation frequency control improvements provide not only an increase in compressor efficiency, but also compressor productivity. This is achieved by installing a rotation frequency controller and/or a valve management controller. When the steam turbine has multiple servomotors, the valve management controller automatically coordinates the servomotors' positions. For example, a steam turbine driving a charge gas compressor in an ethylene plant has five servomotors, while the steam turbine for ethylene compressor has eight. Efficiency can be increased by improving the accuracy of speed control to very tight margins (in our case, .02% of rotating speed).

Further improvements to the hydraulic equipment associated with the control system also provide benefits in this area.

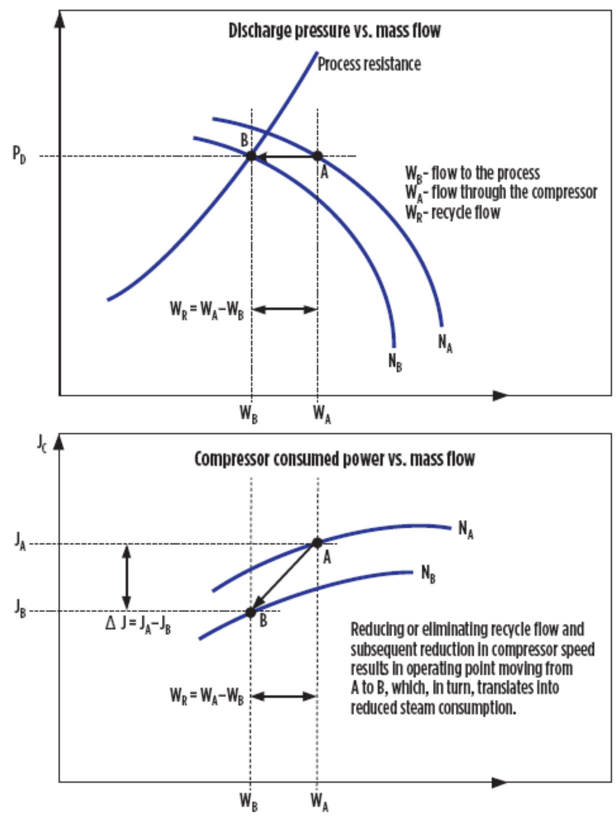

Fig.1. Turbomachinery operating boundaries and power savings at hydrocarbon processing facilities can be increased with proper integration of capacity, anti-surge and limit controls.

Antisurge control system hardware and software integration

System integration with loop decoupling technology among controllers delivers reduced variable deviations that are caused by process disturbances as compared to independent operating controllers. This provides the additional value of reducing the incidence of process disturbances negatively affecting the operation of the compressor and leads to additional energy savings.

Load sharing among compressor trains

System load sharing relates to groups of compressors operating in parallel and/or in series. Many different strategies have been employed to unload and load a compressor station. One common method is to set the speed control manually and run each compressor continuously at full load. Swings in station load are met by recirculation of gas around the compressors. This system is obviously wasteful of energy.
Another common method base loads the most efficient compressors either at their maximum flow or at their point of maximum efficiency. The swings in load demand are then met by modulated control of the less-efficient compressors or by on-off control of these compressors. This system is not energy efficient or sufficiently reliable.
Proper load sharing can increase the efficiency of a group of compressors by:

- Preventing the compressor's antisurge valve or valves from opening while one or more compressor(s) in the group can have a reduction in throughput without recycling
- Loading compressors in a group by utilizing procedures that concurrently minimize total energy consumption

A more effective and energy conscious approach would be to simultaneously adjust the load of the compressors. When properly controlled, this gives the most energy efficiency, the most precise control, better machine protection and improved automation. Regardless of variations in compressor polytrophic efficiency, the station should reduce load so that all the compressors reach their surge control lines simultaneously. This is achieved by load balancing the compressor trains based on equal distance from their respective surge control lines. This load balancing strategy is revered to as "S Criteria". This control strategy requires an effective antisurge system for energy efficiency, as well as for proper machine protection.

Energy savings methodology and implementation

While one can conclude fairly easily that an opportunity to optimize energy cost at a plant exists, the process required to move from concept to execution must follow a strict and repeatable methodology. The approach we follow is in 5 steps, and in many ways it resembles the well-known Six Sigma DMAIC process (Define-Measure-Analyze-Improve-Control).

Step 1: Site Survey

The first step to understand the how much the customer can save requires a site visit which will establish if there is a reasonable opportunity for energy savings.
Preliminary review of the production involves studying the relevant process, compressor, and turbine (or motor) parameters. Not all plants offer sizable energy savings opportunities, and in cases where none are identified the right thing to do is not to move forward. If an opportunity exists then we move to the second step.

Step 2: Site Monitoring

This phase is an ongoing audit of existing process data and typically we expect it to last 2 weeks depending on what data is available and its repeatability. Data may be collected either manually or through process data historians. The goal is to establish operating baseline, and estimate the variability of the operating conditions. Data collected in this phase is reviewed and analyzed by CCC. During this stage, data quality problems are examined through test-retest and detailed review of dynamic data where available. This is a critical juncture: a clear baseline with repeatable and reliable sensors is mandatory for a successful project. Once all issues related to new sensor installation, upgrades, and calibration are resolved, we move to the next phase.

Step 3: Site Assessment

The site assessment offers two deliverables; 1) Formal report and 2) project proposal. The formal report will outline gaps from current energy cost to achievable potential. The commercial proposal will include an ROI calculation and performance guarantee. The methodology for calculation is then outlined to the customer, specifically to the opportunity and available measurements.

Step 4: Site Improvement

This is the phase for contractual commitment to a risk/benefit agreement designed for the specific site. This is the financial agreement that is customized for the specific opportunity and unique to the situation.

Step 5: Site Control Phase

The overall project proposal outlines how long this phase should last and requires machinery running in stable operation with reliable data output to validate results. This is the critical step to measure the achievement of your energy savings and will have a minimum and maximum duration. At the end of this period the data is again reviewed by the technology team and a formal report is presented to the customer. This is the final step to determine if the results are achieved.

Case Histories

Several case histories have demonstrated the measurable benefits of this methodology. Specifically, we would like to highlight two recent examples that illustrate the practicality and benefits of this approach. Following a site audit and study, a new antisurge control system was installed on a multiple stage gas compressor. The new system was commissioned integrating main process parameters, delivering steam savings of 19.3 tons/hr. Similar results were obtained for the propylene and ethylene compressors, delivering respective savings of 12.8 tons/ hr and 9.8 tons/hr. The integration of these variables with the antisurge control system delivered an average efficiency improvement of 5%.

In a fertilizer plant, the operator sought to address a chronic problem related to excessive energy consumption in a motor driven compressor. Following a detailed site audit and report, it was concluded that the plant needed the ability to deploy high precision tracking technology enabling instantaneous adjustment of control parameters while minimizing the opening of recycle valves by the antisurge control system. This enabled the plant to integrate automatic control of gas flow through the suction and control valve, reducing electric motor energy consumption by 18%.

It is important to perform thorough and detailed site surveys and monitoring before assessing eventual opportunities for energy savings. When carried out following a solid methodology, and with the support of qualified specialists, the results often yield multiple values of magnitude compared to the small initial investment, above and beyond the value realized by having gained additional insight into critical plant operations.

About The Author:

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