OPENING THE DOOR TO PEAK PERFORMANCE

Stefano Belloni, Compressor Controls Corp., USA; and Fabio Giove and Roberto Valoti, IMI Critical, Italy, discuss how integrated antisurge control and antisurge valve technology is solving some of LNG's most critical challenges and opening the door to peak performance.

In LNG applications, the reliability and controllability of the gas compression process is critical to achieving stability in the main process parameters. However, LNG applications pose unique challenges, placing them among the most demanding services for antisurge control and antisurge valves. Although many technologies exist for optimising aspects such as antisurge control and antisurge valve positioning, these functionalities are typically siloed, resulting in missed opportunities for efficiency.

Achieving stability and efficiency in LNG applications requires new approaches to operating main refrigeration compressors. This article describes the functionality, testing and proven benefits of integrating the antisurge control and antisurge positioner technologies developed by CCC and IMI Critical.

LNG main refrigeration compressor

When an LNG plant is operating at partial load, its compressor throughput must be reduced. Meanwhile, the antisurge control system could require the opening of the antisurge valve for either antisurge control or process variable control. In this situation, achieving prompt and stable controllability at low-flow is not only critical to stabilising operations, but also minimises the use of open-loop response and consequent process disturbances while maintaining minimum safety margins.

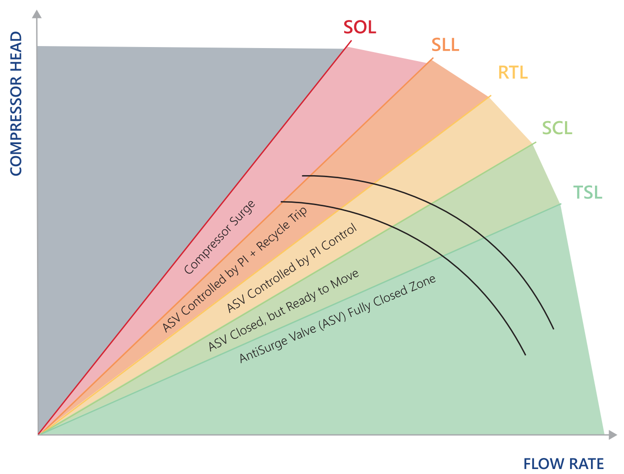

Figure 1. Antisurge control responses.

CCC and IMI Critical have witnessed first-hand the shortcomings of current compressor control strategies, and set about to bridge the gap through innovation. The result is an integrated system that minimises the dead time on seat for large valves and optimises controllability at low-flow operation. Rigorously designed and validated, the team's integrated approach enhances stability, safety margins and efficiency across the connected process.

Performance and antisurge control

LNG plant designs have evolved significantly over the decades. This has led to the adoption of various compressor configurations, including parallel refrigeration machines, multiple services on the same shaft and, in some cases, a combination of the two. Integrating performance and antisurge control responses has proven successful in the operation of large refrigeration machines. These responses include, among others:

- Primary capacity control for the primary process variable.
- Antisurge control for the compressor operating point.
- Limiting control for the limit process variables.
- Pressure override control for response to disturbances.
- Loop decoupling between process-coupled control loops.
- Load-sharing and load-balancing for parallel machines.
- Recycle balancing to equalise recycle rates.
- Domino trip avoidance to mitigate the effects of one machine's trip on the others.

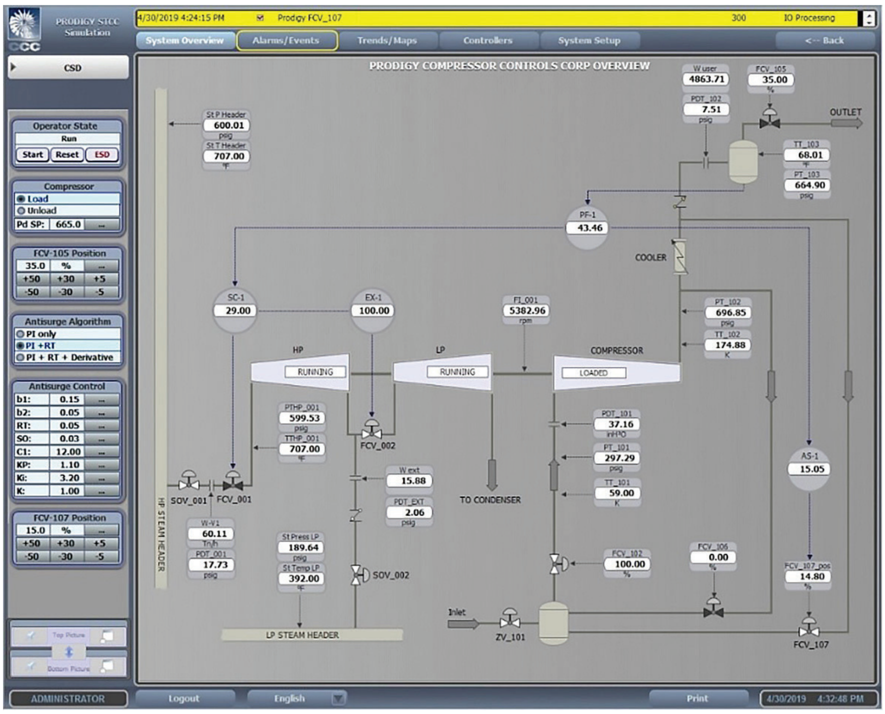

Figure 2. Compression system digital twin.

The CCC turbomachinery control system combines these responses seamlessly to drive the outputs to both the antisurge valves and the performance control element, whether it be the machine's speed, inlet guide vane position or inlet throttle valve opening. The objective is to guarantee the safe, reliable, stable and efficient operation of the main refrigeration machines and, as a result, the connected process.

Antisurge control and tight shutoff line

CCC antisurge control applications comprise multiple lines of control responses. These applications are designed to achieve stable operation on the surge control line, as well as prompt and effective protection when moving further into surge.

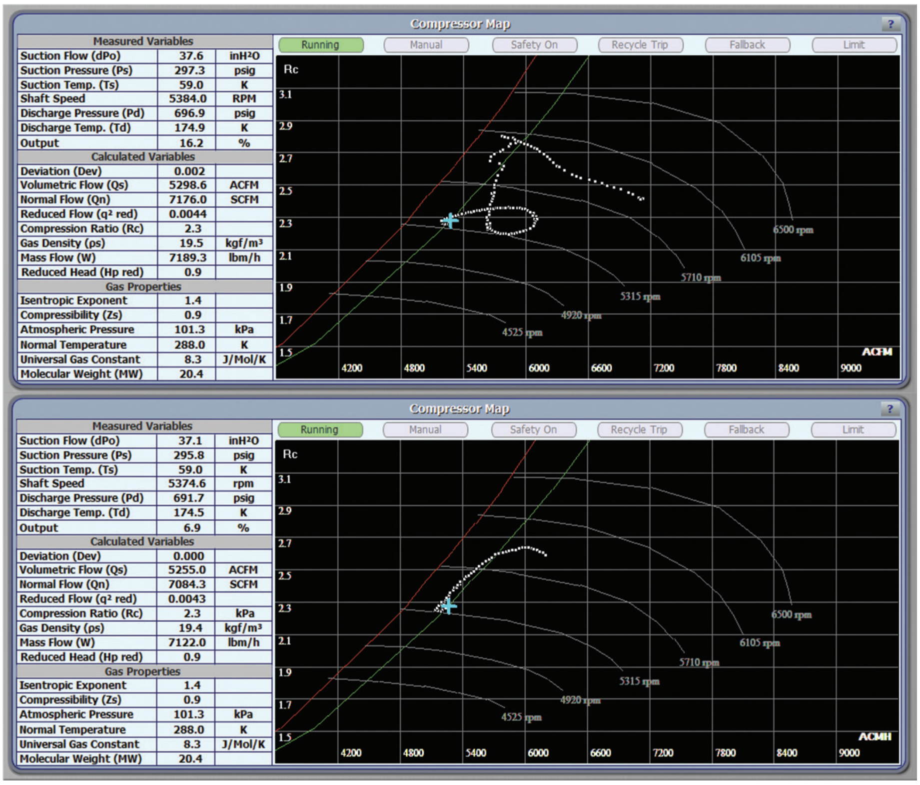

Figure 3. Compression system dynamics without (top) and with (bottom) integrated technology.

Figure 4. CCC Prodigy® control & IMI Critical actuation test bench.

In Figure 1, the antisurge control lines include:

- Tight shutoff line (TSL): pre-positioning the antisurge valve as the operating point approaches the surge control line (SCL).
- SCL: proportional-integral (PI) response for stable operation.
- Recycle Trip® line (RTL): open-loop response for surge avoidance.
- Surge limit line (SLL): actual surge line position in invariant coordinate system.
- Safety On® line (SOL): safety margin increase to avoid surge cycle recurrence.

Some of the above responses include a derivative or multistep response for optimal control.

CCC designed the TSL to keep the antisurge valve fully closed when the operating point is far away from the surge control line (i.e. to the right of the TSL), and to pre-open the antisurge valve to a low clamp, such as a 2% opening, when approaching the surge control line (i.e. to the left of the TSL).

This tight shutoff functionality ensures the antisurge valve is ready to move and reduces the dead time to move out of the seat. However, its effectiveness is limited by the reaction time of the actuating/positioning system of the valve, especially for ones large in size. This system works well for small valves in which the air volume in actuators can be evacuated quickly, even by conventional positioners. But for LNG antisurge valves – or large antisurge valves in general – the size of the actuator is so big that the time needed to evacuate air through the small ports of conventional positioners represents an enormous challenge. For this reason, the time for the valve to react to a small signal – normally between 1% and 4% of full signal range – results in a real movement only after many seconds from the time of request. Many compressor manufacturers assign a limit of acceptance of 30 sec.

Dead Time On Seat Killer

In November 2014, IMI Critical patented Dead Time On Seat Killer (DTOSK) – a functionality that reduces the effective valve dead time on seat. Available for IMI FasTrak® and QuickTrak™ positioners, this technology can transition the actuator from the 'full thrust on seat' to 'floating on seat' condition in a few hundred milliseconds by disconnecting the reaction of the valve from simple PID logic. The transition is triggered by either a discrete signal or threshold on the controller's analog command. In the 'floating on seat' condition, the movement of the valve from the seat is null or negligible, yet the dead time on seat is reduced by a factor of 10.

The result is immediate controllability, with a mere fraction of a second required to react to a small signal to open. On large valves and actuator systems, these numbers are higher, making the reduction of dead time on seat even more critical.

Laboratory testing

IMI Critical and CCC worked together to create a unique test bench, available at IMI Critical and CCC testing labs, in order to demonstrate that their tight shutoff and DTOSK technologies could be successfully integrated and implemented. This test bench incorporated a CCC Prodigy® turbomachinery control system running a compressor digital twin and a physical actuator from IMI Critical. The positioning system was commanded by the CCC control system, with the position feedback used by the compressor simulation to calculate the recycle flow. The actuation system was therefore tested as physical hardware in the loop. Its response affected the dynamic of the overall compressor digital twin.

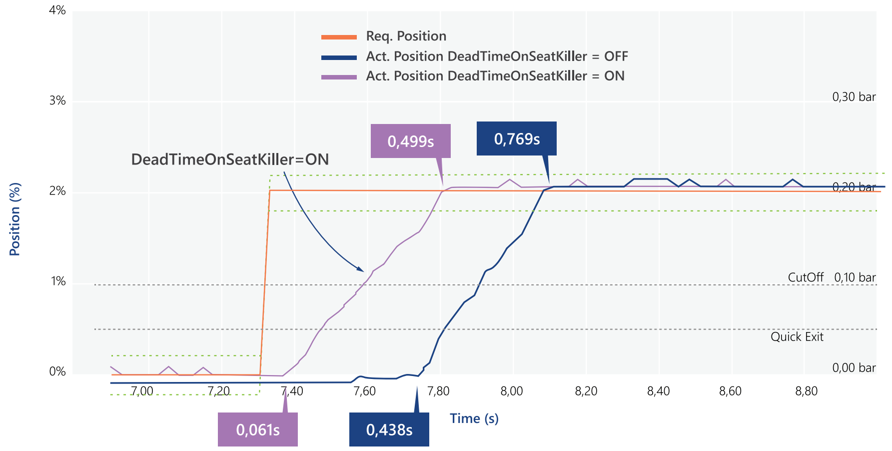

Figure 5. Reduction of dead time on seat by enabling the Dead Time On Seat Killer (DTOSK) on FasTrak® positions.

The actuator could be controlled by different positioning systems: the IMI FasTrak® positioner, featuring a small amount of boosters; or the IMI QuickTrak™, a high-volume positioning system with a stepper motor actuated spool and no boosters. These positioning systems were configured to satisfy the current dynamic performances required by the world's key compressor manufacturers, with all of them able to meet the stroke time of fewer than 2 sec., including dead time. The actuator was medium-sized and normally used on roughly 12 in. valves. If the same tests were conducted on the large valves used in LNG applications, it would lead to more significant differences in reaction time.

The digital compression system (Figure 2) consists of an extraction steam turbine that drives a single-stage compressor. A throttle valve, located on the discharge header, was used to simulate process disturbances by partial step closing. The same type of disturbance was replicated by connecting the different positioning systems to the actuator and then enabling and disabling the integrated tight shutoff and DTOSK. Tests were conducted to simulate both small and large disturbances; the difference in actuation system responses is clearly illustrated in Figure 3.

In the first case, the actuator dead time leads to the Recycle Trip® response and step open of the antisurge valve, with the operating point having visible fluctuations across the compressor map. In the second case, the reduced dead time and prompt response allow the PI response to control the disturbance alone. The operating point is controlled directly on the surge control line while the throughput reduces.

Benefits of integrated antisurge control and antisurge positioner technology

By integrating their antisurge control system and antisurge positioner technologies, CCC and IMI Critical developed a new solution for maximising both overall system performance and end-user benefits. When integrated, the TSL and DTOSK directly impact the controllability of the compressor operating point and, eventually, the safety margin required for a safe and stable operation.

Defined as the distance between the SLL and the SCL, the safety margin depends on multiple factors:

- Piping layout.
- Volume between discharge of the compressor and the antisurge valve.
- Shape of the compressor performance curves in the region approaching surge.
- Turbocompressor inertia.
- Accuracy of the surge testing data.
- Instrument signal-to-noise ratio.
- Antisurge valve dynamic performance.

Just as antisurge valve dynamic performance is an important factor, dead time on seat is an important parameter that requires higher levels of attention in the design and selection of antisurge control system and antisurge valves. The reduction of the dead time on seat allows the control system to effectively control the operating point when reaching the surge control line and minimise excursion of the operating point on the left. This is important both during slow reductions of the compressor throughput and fast disturbances. Especially in the second scenario, a delayed opening of the valve in respect to the control output can lead to the operating point reaching the RTL. While the open-loop step open Recycle Trip response is warranted to effectively bring the operating point into the safe operating area, it also generates significant flow instabilities. Therefore, the objective of a well-designed system should be to minimise the intervention of the Recycle Trip response while maintaining tight surge control margins. The integration of antisurge control system and antisurge valve actuation technologies helps achieve this objective.

The benefits of integrating antisurge control system and antisurge valve technologies extend beyond the compressors. Ultimately, this approach delivers key value for the overall process by expanding stable operations in areas of reduced throughput and high efficiency. The reduced recycle also contributes to decreasing energy consumption and related carbon emissions. **LNG**