



Expertise in Turbomachinery Controls

WHITEPAPER

Taking Control



Publish Date: 1/18/2012

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This paper discusses the value of an effective compressor control system and the problems it may prevent.

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There is a growing need to diversify our energy supply choices. Natural gas has become a viable choice, but presents the challenge of transporting the gas from production site to consumer. Pipelines are not always available. An efficient means of accomplishing transportation is in the form of LNG.

The design of an LNG plant is based upon differing liquefaction processes. One process incorporates a refrigeration cascade, another is a multi-component refrigeration process (MCR) and another is a pre-cooled, propane mixed refrigerant. The compressors used in the plant design are among the most critical and expensive pieces of equipment.

A compressor in an LNG plant is a sizeable investment and ongoing expense. Equipment failure and shutdowns are major risk events that significantly impact not only the plant's production, but the equipment's life cycle. The main purpose of a compressor system is to maximize the production throughput and enhance product quality. An integrated control system for the compressors is highly critical for safe, efficient and reliable operations. These control systems are utilized to protect the compressors from risk events such as surge, suction pressure, and control element failure.

Careful review of compressor processes and controls has proven that a well-designed and integrated control system, incorporating automatic throughput controls, is crucial in the operation of plant production. Identified problems such as compressors that operate at fixed throughput, compressors in parallel, compressors in series, manually changing speed set pointing to the fuel control system or adjusting the plant to account for ambient and process condition changes and production demand.

Often used as a control process for LNG plants, product temperatures are maintained within tight margins, thus there is no direct control of production rates. The goal is to maximize flow rates by adjusting the available refrigeration cycle duty, while maintaining desired product temperature.

Another popular philosophy is maintaining a desired flow rate in addition to consistent product

temperatures within tight margins. With an estimated production cost of US\$ 200/t, it is critical to keep the plant operational. Any negative event has the capability of affecting the production and cause equipment damage. Also, complications from undesirably high temperature gradients in the cryogenic equipment may cripple equipment and cause major losses in production. With some plants producing an estimated 20 000 tpd, the financial ramifications of a shutdown are significant.

Surge control

Prevention of surge events for compressors is a significant challenge facing LNG production. Compressor surge is characterized as a sharp drop in discharge pressure and flow rate, including a flow reversal, and is a significant process event even when turbomachinery is kept online. The potential consequences of mechanical damage and process downtime make the elimination of surge events a necessary production goal because of the costly consequences. Surge is a risk element that will disrupt or trip the process and damage the compressor, seals and bearings. Seal clearances are increased as a result of surge, lowering compressor output and efficiency through internal recycle.

To prevent such a loss, an effective anti-surge control system is necessary for every compressor to protect both it, and the process. The design of a surge-control system should be regarded as a necessary design practice and effective risk-mitigation measure. The surge-control system is an important component in the compressor system because it protects the compressor from surge over the range of compressor operations. The control system must be capable of accurately predicting the varying position of the surge line, of operating at varying conditions continuously, and of providing automatic, 24/7 surge control of the system. In addition to preventing equipment damage and financial loss, an effective anti-surge control system also provides substantial energy savings by reducing recycle during operation at reduced process throughput.

Appropriately sized and properly well engineered

antisurge recycle valves are critical for surge protection and results in valves that are sufficiently sized and fast enough in response to handle normal operation of the compressor. The valve must be large enough to prevent surge under all possible operating conditions, including startup and shutdown without being too large. An oversized valve will provide poor control precision and will drive the compressor into choke flow when fully opened. Opening this valve reduces the process discharge resistance, typically reduces the pressure differential across the compressor and increases the flow rate through the compressor. All of these actions move the compressor operating point away from surge. The key factor of surge protection is determining when and how much to open or close the recycle valve.

Suction conditions

Suction conditions for compressors change continuously. A surge-limit line, defined by the antisurge algorithm, should not vary with suction condition changes. Compressors typically have a family of surge-limit lines as provided by the OEM. The variances include speed, guide vane angle, gas composition, suction temperature and suction pressure. The antisurge algorithm should take into account these varying suction condition changes.

Surge parameters

Surge parameters are also critical. Sidestream flows of a compressor present different challenges to antisurge control design. A compressor's internal design prevents the direct measurement of flow for the inside compression stages, which do not allow a direct measurement of suction or discharge flow. As a result, algorithms using principles of mass balance are necessary to calculate this flow.

The compressor control systems must be able to provide an accurate calculation of these indirectly measured flows using flow measurement algorithms. The compressor control system must be able to fluctuate within the interactions between the control systems within the separate compression stages of the compressor.

Automatic (not manual) startup and shutdown

Quickly starting and maximizing LNG production is important in greenfield LNG plants. Making sure the antisurge control system provides and assists in an automated fashion ensures that the compressor is automatically loaded and unloaded during startup and shutdown without operator intervention.

Constraint control

An effective antisurge control system may be responsible for opening the recycle valve even when operating conditions are far from the surge limit and must guarantee that safe operations are never sacrificed. The control system should optimize performance within the safe-operating envelope, allowing for maximum throughput for a given constraint.

Process and equipment design constraints may require a capacity control system to restrict compressor throughput, minimize process upsets or overloading the drivers. Performance or capacity control then becomes part of the overall turbomachinery control system that interfaces directly with antisurge protection.

Load sharing

Load should be distributed between parallel compressors in an appropriate manner based on the feedback of the distance from surge calculation performed in the antisurge control. This feedback is necessary for load sharing and load balancing to provide precise process control which is typically a suction pressure setpoint. This method maximizes the compression envelope while at the same time complimenting the antisurge control function. It also prevents any one machine from being power limited when another parallel machine has reserve horsepower or additional room in its compressor operating envelope.

Decoupling

Control of multi-stage (series) compressor units is yet another challenge facing LNG plants. Refrigeration and feedgas compressors of LNG plants operate at high discharge pressures, resulting in a multi-stage design.

During the startup and part-load operating stages, compressor recycle valves are controlled under the antisurge control actions.

Compressors operating in series must co-ordinate the opening of antisurge valves between the low pressure and high pressure stages. For example, opening a low pressure stage recycle valve reduces flow to the downstream stage and pushes the high pressure stage closer to surge. Closing the low pressure stage recycle valve will drive the downstream stage away from surge.

Therefore, the respective antisurge control valves for a multistage machine must be coordinated in either direction, i.e., if the upset comes from the discharge or suction. This is where feed-forward decoupling comes into play between the respective antisurge valves, and ultimately between antisurge protection and the capacity control of the turbocompressor. It is a matrix of interaction directly proportional to the number of interacting loops. This control functionality is of keen importance to keep control loops from interacting and causing a much larger process upset. The feed-forward or decoupling action is the main stabilizing force to prevent a minor process upset from becoming a flaring incident or a worst case surge event for the subject machine.

Conclusion

LNG plants present challenges in regards to turbomachinery operation and control. Minimizing and resolving these control issues requires an effective control system dedicated and designed for the specific application. The capital cost for turbomachinery is large, so protecting this investment is a major objective. Additionally, equal consideration should be given to maximizing the LNG production of the facility when choosing a turbomachinery control solution. By using an efficient, well designed turnkey compressor control system to simplify startups, decrease downtime and aid in the prevention of machine damage, both of these critical objectives can be effectively met.

References

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