



**Compressor Control:
Maximizing Safety and Efficiency**

**Emerson Solution for Optimal
Turbomachinery Control**



Getting more while spending less...

With today's global competition and the need to minimize costs, more and more producers strive to operate their compressors at maximum efficiency. At the same time, companies must ensure that their plants can operate under high or low load conditions to satisfy market demand. Meeting these objectives requires expanding the safe operating zone of the compressor.

Compressor automation is the key to maximizing efficiency. Reliability, safety, production rate, and energy savings are the major factors.

Barriers to maximum efficiency:

Expensive and inconvenient "black boxes"

A separate local system from the OEM or third parties often requires special treatment for service or maintenance. Quick tuning, re-configuring, or troubleshooting these systems by site operational personnel is a challenge. In addition, compressor parameters can be difficult to compare with the Distributed Control System because their archival systems are often not synchronized.



Ineffective control algorithms

The simpler algorithms used, the bigger safety margins required and, therefore, the less compressor operating range is available.



Wasted time for manual operation

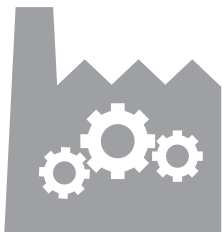
A unit shutdown can be very costly. Manual startup and shutdown procedures take significantly longer than automated procedures.



Excessive energy consumption

Operating outside the compressor's maximum efficiency zone, excessive recycle or blow-off, or lack of coordination between parallel or serial compressors can all lead to higher energy consumption.





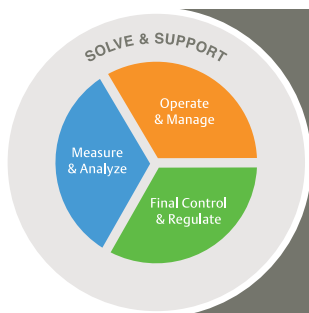
Compressor operation is critical for the entire process unit. High quality compressor controls can reduce unit idle time, increase unit capacity and lengthen compressor life - all leading to lower cost and improved competitiveness. Adding indication of machinery health and additional instruments will improve decision making and increase the overall unit energy efficiency.

Integrated Emerson turbomachinery and process control solution

Turbomachinery control is an important part of the control architecture of those plants where compressors are critical for production.

An integrated Emerson turbomachinery control solution provides the following features:

- Safe and efficient antisurge control
- Steam and gas turbine control
- Load sharing between parallel compressors
- Auxiliary device control
- Mechanical state monitoring and diagnostics
- Modifications of pilots and actuators
- Antisurge valve optimization
- Valves and instrumentation diagnostics
- Maintenance procedures optimization
- Consultancy on process optimization and good practice of turbomachinery operation



Emerson complete solutions are designed to help your plant boost performance, safety, reliability, and energy efficiency.

- Turbomachinery control • Wireless solutions • Vibration analysis
- Safety instrumented system • Industry solutions • Advanced process control
- Operator training solution • Integrated operations center



Surge and antisurge control

What is the surge and why it's actually bad?

Antisurge Control - pg. 6

Ways to improve compressor efficiency

How to increase the compressor efficiency?

Efficiency - pg. 8



Surge and antisurge control

Surge and related mechanical consequences for a compressor can have serious economic penalties for the plant. For example, a shutdown of the catalytic cracking unit in a refinery can cost over \$1M per day excluding repair costs.

What is the surge?

Surge is a phenomenon where flow oscillations inside the compressor are created when the pressure ratio across the compressor becomes so high that it's restricting the gas flow sufficiently to cause a stall. When the flow drops to a critical minimum level, the gas flow becomes turbulent and separates from the blade surface. At that moment compressor partially loses its ability to transfer energy to the gas and the gas under natural forces starts flowing in the opposite direction - from discharge back to suction. When this occurs, pressure ratio drops and compressor recovers the flow direction. If no action is taken, this process repeats again and again.

Why is the surge dangerous?



Flow direction in the compressor reverses at the moment of surge so the shaft experiences cyclical load changes in the axial direction. At the same time, imbalance of the acting forces on the rotor causes chaotic movement of the shaft in the radial direction. All of this can cause damage to the seals, bearings, shaft, blades and internally-mounted sensors.

In axial compressor cyclical changes in the force direction can break a blade with all possible consequences. Centrifugal compressors are not prone to this type of damage, but the damage of the working wheel is possible.

Gas is heated during compression and at the moment of surge this heated gas flows to the suction and then gets heated again and again. High temperature can cause a safety trip, or worse, lead to temperature-dependent damage to the shaft and rotor.

Surge and its consequences are very well known to plant personnel. Surge poses a threat and is the subject for a complex set of preventive measures to reduce the risk.

What opportunities do you have?



Precise algorithms, modern controllers, sensors, transmitters, and valves from Emerson allow you to significantly decrease the risk of surge.

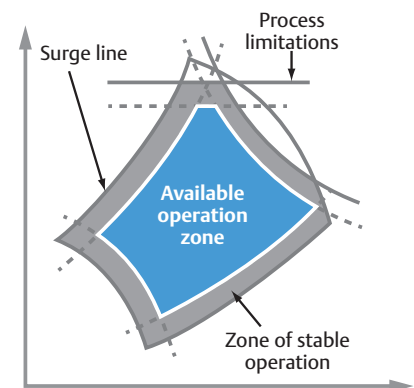
Even if surge is inevitable due to a severe process upset or other reasons, the Emerson antisurge system will instantly detect surge and immediately react to stop it.

Advanced diagnostics of valve and transmitter health available from Emerson devices eliminate false trips and yet, won't miss real failures.

What advantages are provided by antisurge control?

Antisurge control provides regulation of compressor parameters to maintain minimum flow through the compressor to avoid stall and surge. High-quality antisurge control from Emerson allows stable compressor operation even during large process load variations. At the same time, complex multi-stage algorithms allow safe operation through a higher range of flow rates.

Emerson's Antisurge Control System can be setup with a minimum possible safety margin and provides more flexibility with compressor load to maximize the efficiency.



Ways to improve compressor efficiency

For processes where compressors have critical impact on the unit operation, the concept of efficiency goes well beyond energy savings.

A complete compressor control system needs to consider such things as safety instrumented systems, elimination of false trips, valve performance, instrument diagnostics, mechanical condition monitoring, start/stop procedures and response to dynamic load changes.

Emerson provides a complete technical solution and methodology backed up by engineering expertise to help solve each of these problems. Emerson's approach treats the entire compressor and the processes attached to it as an asset to be optimized.



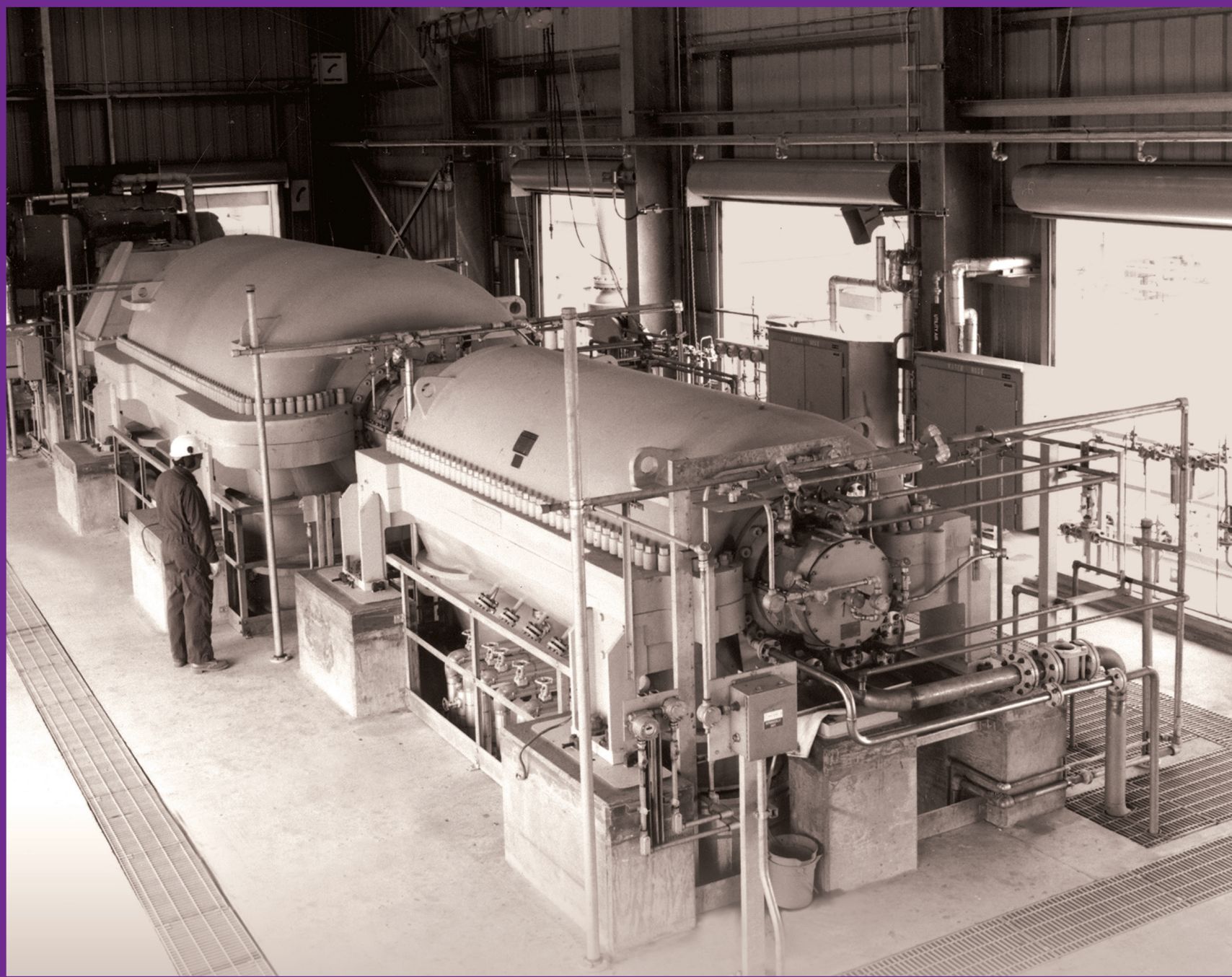
What are the sources of inefficiency?

Excessive recycle, variability in control, false trips, lack of visibility in control system, limited online monitoring and diagnostics along with difficult access to spare parts and lifecycle support are examples that lead to increased cost of ownership.



What options do you have?

An integrated solution for a compressor, its drive, valves, instrumentation and process control, all joined together with advanced condition monitoring and instrumentation diagnostics - optimizing compressor operation and providing actionable information for real-time decision-making.



The power consumed by the compressor is proportional to the gas flow through the compressor. The key to compressor optimization is to deliver process needs with minimum possible flow through the compressor. In other words, minimize recycle or blow off.

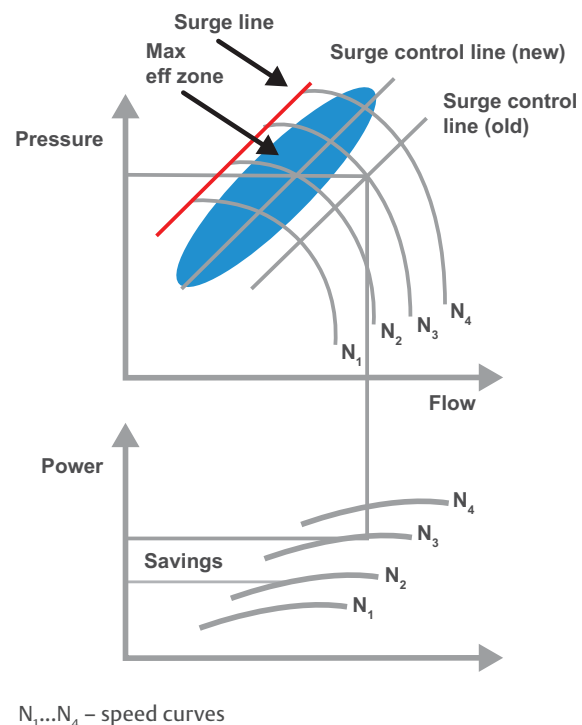
Optimization of energy consumption for one, or a group of compressors

Optimization of compressor energy consumption

The total compressor flow is a sum of the flow that it sends to the process and the recycle (or blow-off) flow through the antisurge valve.

First, and the most efficient way to decrease the compressor energy use, is precise antisurge control, from the measurement to the control algorithm to the antisurge valve. Knowing where you are relative to surge and how fast you can respond sets the required safety margin. A quick response allows safe operation closer to the surge line.

This approach protects the compressor from surge with a minimum possible opening of the antisurge valve. Emerson offers a state-of-the-art solution based on market-leading components and expertise that delivers the maximum results.



Second way to minimize energy consumed by compressors is known as performance control or load control - essentially stabilizing the main process parameter (e.g. discharge/suction pressure or flow) in the optimum way.

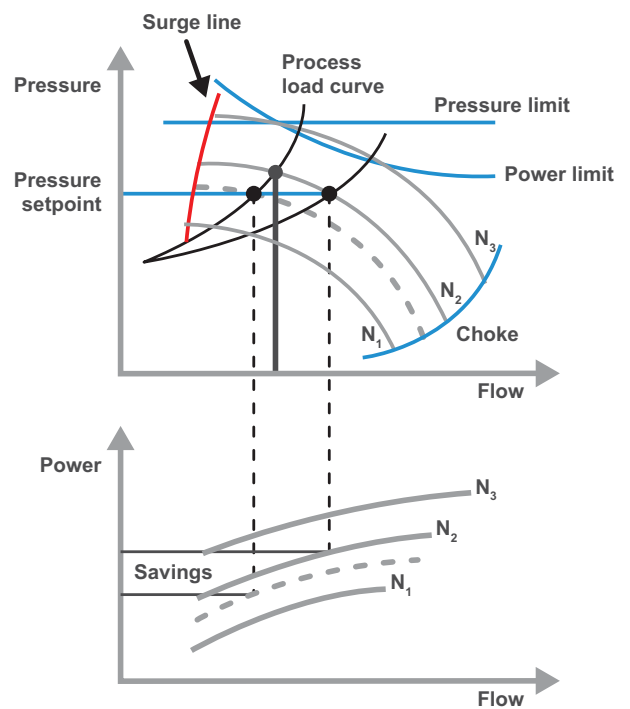
Depending on the process and compressor design, the control system will manipulate available control parameters to achieve stable control at minimum costs. i.e. at maximum efficiency.

Adjusting shaft speed is the most efficient way to control a compressor. Throttling the gas at the suction of the compressor is the second best option for control. Opening the antisurge valve is the least efficient way to control the compressor because the gas gets throttled right after it was compressed.



The drawing on the right illustrates how manipulating shaft speed can increase the overall system efficiency and lower the energy consumption.

If the main process parameter is pressure or pressure ratio (**Point 1**) then decreasing process load will shift the operating point along the compressor performance curve to **Point 2**. Opening the recycle valve will maintain the operation at **Point 1**, but at the same energy consumption since the flow does not change. Alternatively, lowering the shaft speed will move the compressor to **Point 3** which reduces gas flow as well as energy consumption.



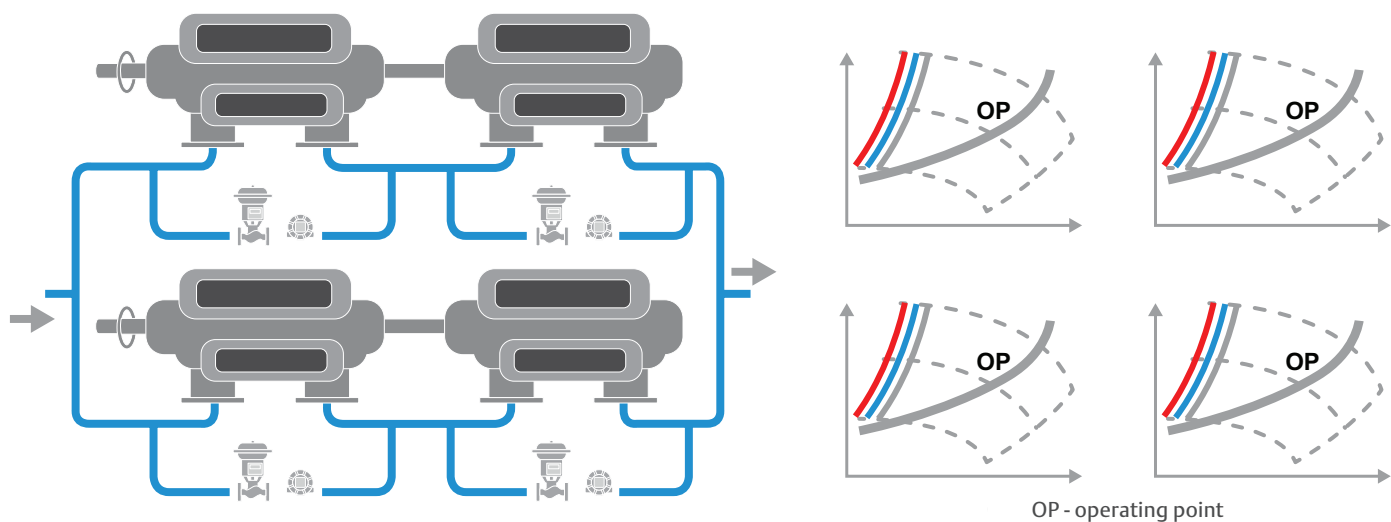
Energy consumption optimization for a group of compressors

When two or more compressors are working in parallel to control a single process variable (e.g. suction or discharge header pressure), it is critical to balance their load to minimize total energy consumption. If not balanced properly, one compressor can take most of the load while others may need to open their antisurge valves to maintain minimum flow. In this case all of them are operating far from their maximum efficiency zone, consuming significantly more energy than they could.

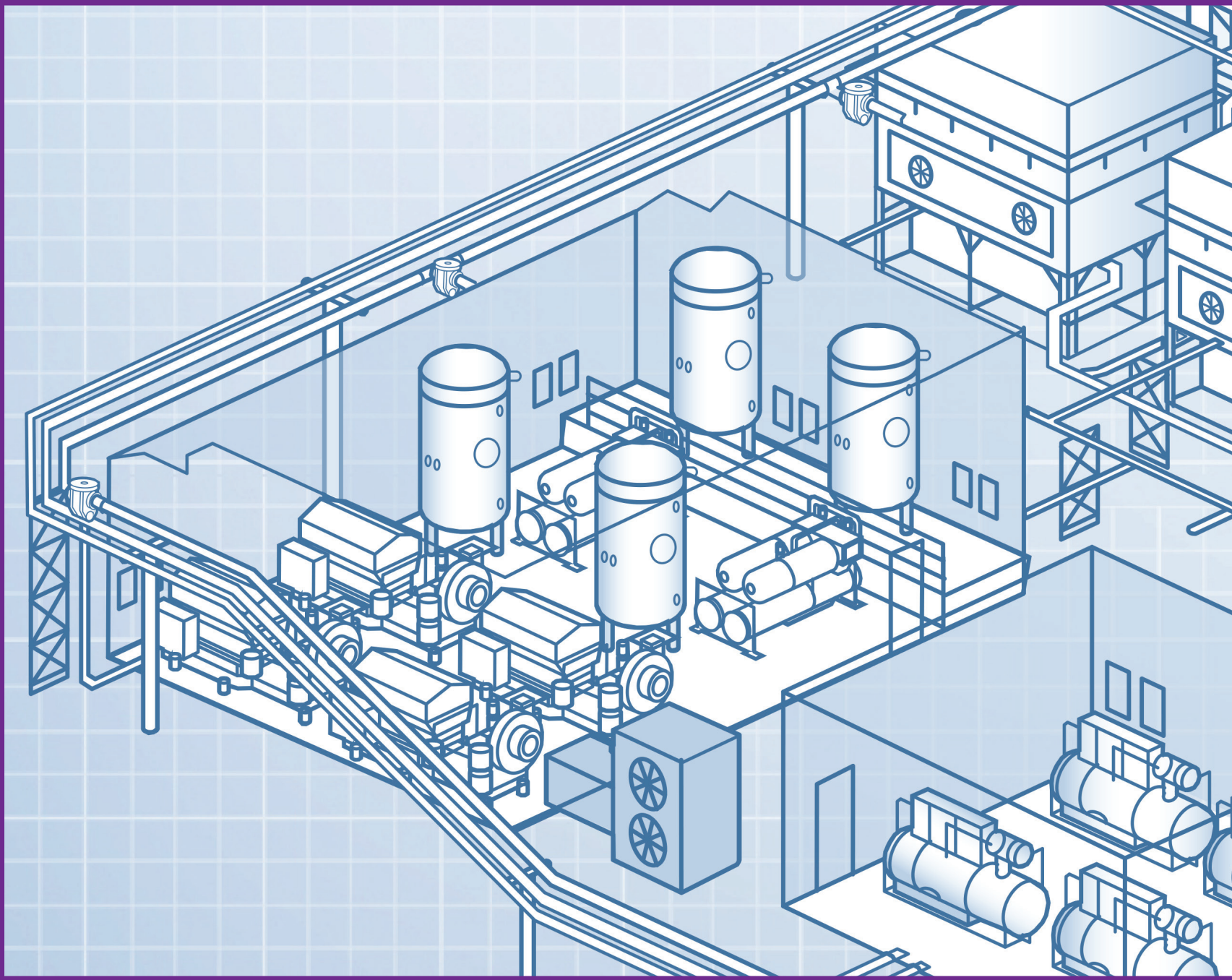
If the compressors are working in series, with individual recycle or blow-off, then opening any of the antisurge valves significantly impacts the flow through the companion compressors both upstream and downstream.

To avoid the situation where one of the compressors blocks or takes flow from the others, the behavior of their antisurge systems must be coordinated with a special load sharing algorithm. It is designed to drive the compressors to their zone of maximum efficiency, given the current process conditions and load.

For compressors working in parallel and series simultaneously, as shown on the drawing below, the algorithms are combined to ensure safe and efficient operation of the compressors, particularly in the face of changing process demand.



Optimizing efficiency: In case of parallel or series compressor operation, each compressor has its own unique compressor map as symbolically shown on the right.



A special Emerson load-sharing and loop decoupling algorithm has the following advantages:

- Coordinated load control for all compressors
- All compressors simultaneously reach their antisurge control lines
- Load sharing for optimal steam, fuel gas, or electricity consumption
- Automatic sequencing for start, load, unload, and shutdown procedures

Control System and Turbomachinery Control solutions from one vendor



Integration is key for lowering costs

Including all functionality in one system, from one vendor, eliminates the need for external boxes and interfaces to connect systems. It also reduces training requirements as personnel are working with familiar DeltaV hardware and software.

Project startup is faster and easier when all factory testing is done as part of the control system Factory Acceptance Test (FAT), including the configuration and simulation of the process and compressor control. All equipment arrives on site fully tested and pre-configured.

High-speed, digital transmitters from Rosemount; Specially designed anti-surge valves from Fisher with air boosters and cushioned seats; All components engineered, configured and tuned by Emerson experts to deliver optimal performance and precise anti-surge control.

Aftermarket services are provided by one vendor, including the anti-surge control as well as the valves and transmitters in the system. All modifications, updates, modernization, tuning (e.g. surge testing) can be performed by one Emerson team and our local business partners.

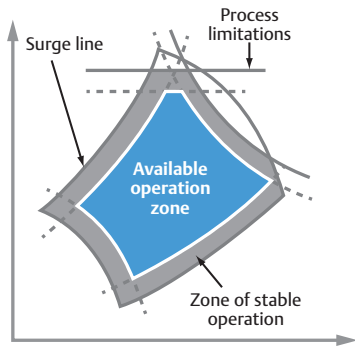


The Emerson Turbomachinery Solution is developed on a basis of many years of experience with design and commissioning of antisurge systems. Our global engineering teams deliver projects and support from their local office, ensuring the fastest project deployment and on-site services.

Combining the power of DeltaV with the ability to perform high-speed calculations in a digital Rosemount transmitter, a new solution for anti-surge control is born. One that can be delivered as standard modules in a DeltaV library, running in a single hardware/software platform.

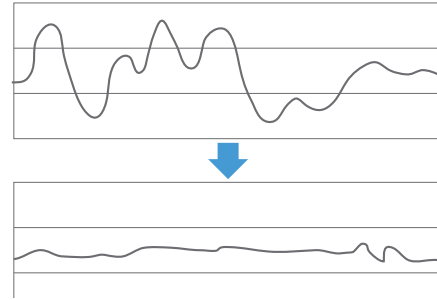
Technology advances

Extended zone of safe operation



Advanced antisurge algorithms and control strategies allow the safe operating zone to be expanded. This helps decrease energy consumption when working close to the surge line and increases flexibility of the unit load.

Improved control of the compressor main process parameter



Integrated control of the compressor and its driver improves stability of the process when working under a variable load.

New level of integration



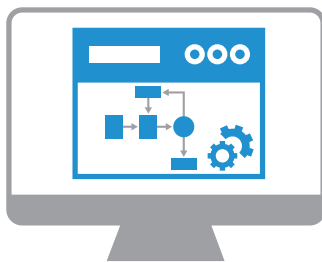
Emerson can supply a complete solution including DeltaV control system, turbomachinery control, vibration and health monitoring, valves and transmitters - all from a single supplier. The system can be designed, commissioned and supported by one company throughout the entire asset lifecycle. This allows Emerson to deliver the project faster, with better quality, and at the same time, lowering the total cost of ownership.

Compressor Load Sharing



A modern approach to the load sharing of parallel compressors allows optimization of energy consumption, stabilization of process parameters, and fully automated start/stop procedures.

Predictive Analytics



Compressor process and mechanical parameters are monitored online and analyzed by a specialized software that is tuned to detect deviations from normal operation and provide suggestions of possible reasons and places to look closer. A highly sophisticated set of functions with feedback correction, a Neural Network, is studying compressor operation and predicts unit failures long before parameters reach dangerous zone.

More instruments for making decisions



Equipment vibration, instrument drift detection, advanced diagnostics for valve and transmitters, all combined with Emerson's on-line condition monitoring solutions provides information for improved decisions.

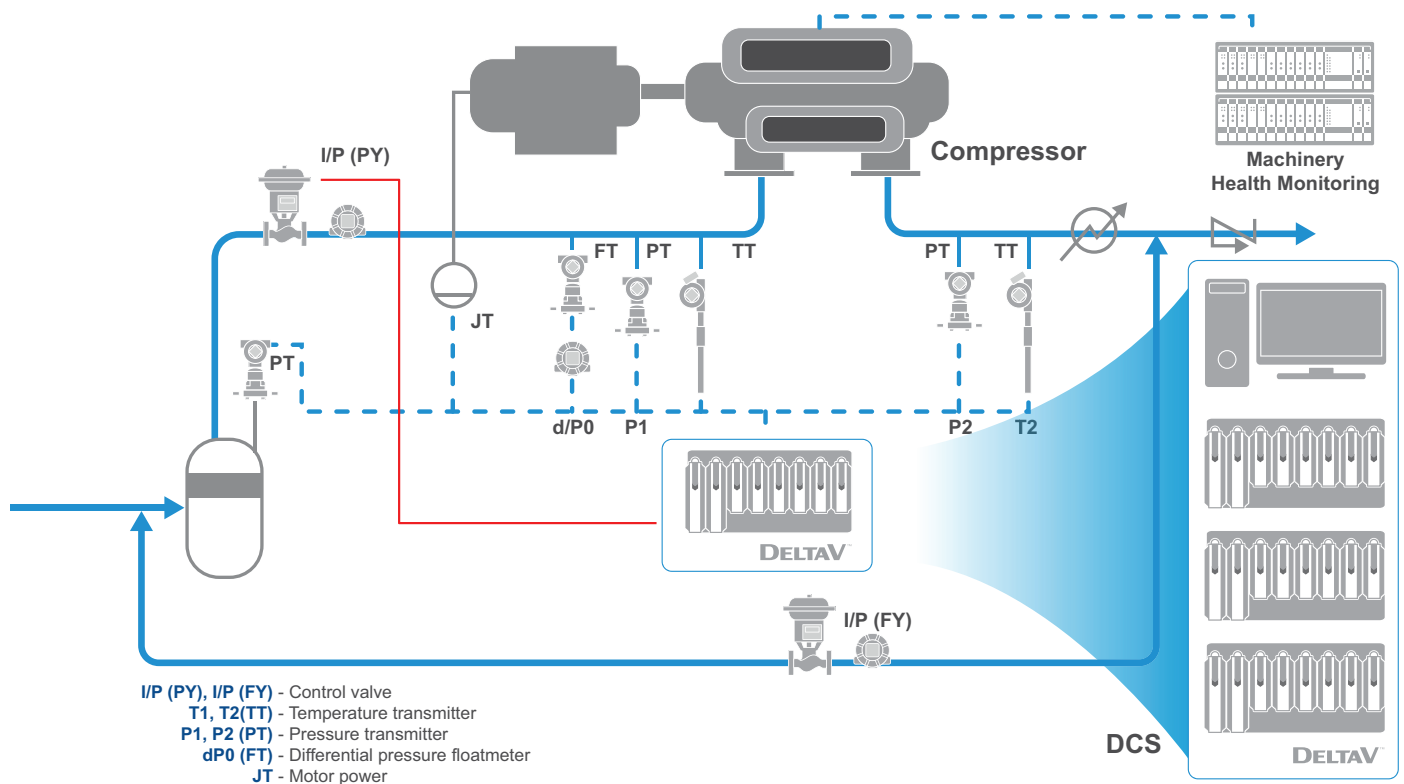
Functional design

A turbomachinery control system consists of numerous components, i.e. transmitters, controllers, valves, inlet guide vane drives, turbine governors etc. Our experts help specify the appropriate devices that match the specific requirements for each compressor. It is the integrated performance of the whole compressor control system that determines the final quality of control, and thus, the economic benefits generated by the system.

The system architecture shown below is a very common solution for an electric motor-driven compressor where the total flow is controlled by the suction throttling valve and the antisurge control is provided by recycling the gas from the discharge to suction. The Operating Point is calculated based on the flow measurement at the suction, pressure measurements at suction and discharge, and temperature measurement at suction and discharge. The main process parameter is the suction vessel pressure. An example of such a system can be found at almost any FCCU. Wet gas compressor control is typically arranged as shown below. It can have two stages on bigger units. A fully functional solution for such a compressor includes vibration monitoring, mechanical condition diagnostics.



Emerson's turbomachinery control solutions are designed and engineered to bring the maximum value to the end user. The DeltaV anti-surge and load control algorithms were created by our Turbomachinery Center of Excellence as a library of control functions and displays, pre-engineered, tested and supported worldwide. A distributed network of Emerson engineering and service offices as well as the Local Business Partners stands ready to deliver solutions at any point in the world.



The Emerson Turbomachinery Control Solution with its precise algorithms of compressor antisurge and load control guarantee the maximum efficiency and safety of the unit operation.

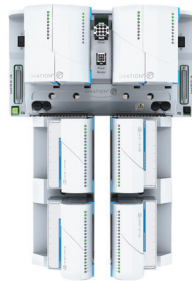
System components

DeltaV M-series, S-series or PK controller



A special unique approach to performing high-speed calculations for surge detection in the transmitter makes the DeltaV control cycle sufficiently fast for surge control.

Ovation Controller



A control module that was designed for high-speed control of gas and steam turbines in a wide range of applications.

Fisher Antisurge Valves



Fast enough to allow the compressor to operate as close to the surge line as possible. Optimized valve performance, together with online tuning make this valve unique for antisurge applications.

DeltaV SIS



Proven and reliable DeltaV SIS equipment allow avoidance of emergencies and fully complies with the API 670 requirement to have a separate dedicated surge detector as a safety function.

Rosemount Intelligent Transmitters



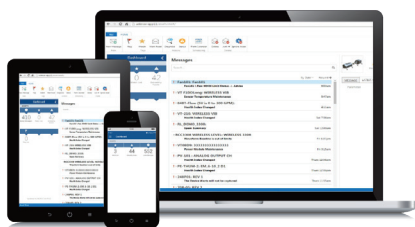
Fast and precise Rosemount transmitters are used in the state-of-the-art, patent-pending Emerson solution for derivative-based antisurge control and parametric diagnostics to detect more types of failure but also avoid false trips.

AMS 6500 ATG



Emerson's AMS 6500 ATG combines field-proven protection capabilities with API-670 compliant protection in a single chassis. It detects and reports developing faults in rotating equipment, including gas-dynamic instability. The AMS 6500 ATG comes in both a traditional rear-access and front-access chassis for easy installation.

Plantweb Optics



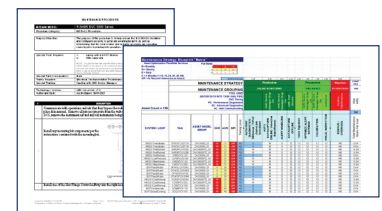
Plantweb Optics is the asset performance platform for managing asset health across the enterprise. Plantweb Optics combines the data from multiple applications into asset-centric information to deliver persona-based alerts and KPIs for production assets.

KNet



Using advanced pattern recognition and machine learning techniques, KNet software predicts failures and abnormal conditions for compressors prior to them occurring. Using a combination of statistics and temporal reasoning, KNet monitors compressor's abnormal operating modes in real-time and informs the user when there is a deviation from ideal performance targets. These predictive modeling techniques also allow KNet to estimate key performance indicators of a compressor such as remaining useful life and predicted time to failure.

Reliability Consultancy



Emerson's Reliability Consulting group adds the deep asset-reliability consulting expertise to Emerson Automation Solutions' asset management capabilities to help customers who face growing needs to improve safety, increase plant uptime and reduce maintenance costs. Combining reliability-consulting expertise with Emerson's monitoring and predictive diagnostic technologies helps customers solving reliability problems and achieving world-class operating performance.

Project delivery stages

Emerson's turbomachinery control solutions has been developed by the global center of excellence, with engineers who have many years experience designing, specifying and commissioning antisurge control systems. Emerson can deliver the best technology to the project, both from Emerson's portfolio as well as 3rd parties. Emerson will take full responsibility for all components of the system to reduce project overhead and ensure on-time delivery. Our worldwide network of engineering offices, combined with our Local Business Partners provide local services to install and commission the solution as well as follow-on maintenance and repair services for the equipment.



Project initiation

A detailed study of the compressor anti-surge requirements for efficiency and safety will be performed. Emerson's turbomachinery control consultants will lead the study with support from various Emerson experts on valves, transmitters, sensors and control equipment.



Project kick-off

A meeting to discuss the process unit operations, existing equipment, performance criteria, economics, etc. to identify an optimum compressor control solution. Emerson's consultants will discuss best practice and the various options available. The final strategy to upgrade which components of the anti-surge system is jointly agreed and documented in a Functional Requirements Specification. From this, a firm project cost can be developed.



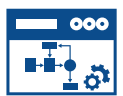
Creating the project specification

Emerson's turbomachinery consultant will lead a team of equipment specialists to define the specifications for any new equipment. A detailed project plan is developed. From the specifications, equipment can be ordered.



Project documentation

Emerson produces a complete set of documentation that includes: Functional Requirements Spec, Detailed Design, Installation and Configuration Guide and User Guide.



System Configuration

Standard algorithms are embedded in a number of function blocks and templates that are configured specifically for each installation. Emerson's local engineering offices configure the templates according to the specifications outlined by the turbomachinery consultant.



Factory Acceptance Test (FAT)

Control System assembly is staged and tested at Emerson's or partner's premises. Customer's participation in the FAT is optional.



Equipment delivery. Supervising and commissioning. Transfer to operations

FAT and site acceptance testing (SAT) are done with a dynamic simulation of the turbomachinery operation. If the turbomachinery control is a part of the DeltaV DCS environment then the testing of the process and turbomachinery control is performed simultaneously. The customer witnesses the SAT and may optionally witness the FAT.



Training. Lifecycle support

The project will include a full set of training courses on the operation and maintenance of the full compressor control system. Emerson provides 24/7 lifecycle support services for our control systems through our Global Service Center with a toll-free number that is staffed by knowledgeable service engineers. These engineers can assist with most technical issues related to the control system. For questions related to the anti-surge applications, the calls will be escalated to our turbomachinery consultants. Local support for the instrumentation and control valves is provided by our local service centers and partners.

Economic Benefits

The Emerson Turbomachinery Control Solution provides energy savings up to 25% by precise regulation of the turbomachinery parameters to safely operate closer to the surge zone. It allows decreasing the amount of recycled gas and stabilizing the process parameters, thus minimizing energy consumption (electricity, steam, or fuel gas). The solution offers a significant improvement in the compressor's energy efficiency.

Energy savings up to 25%

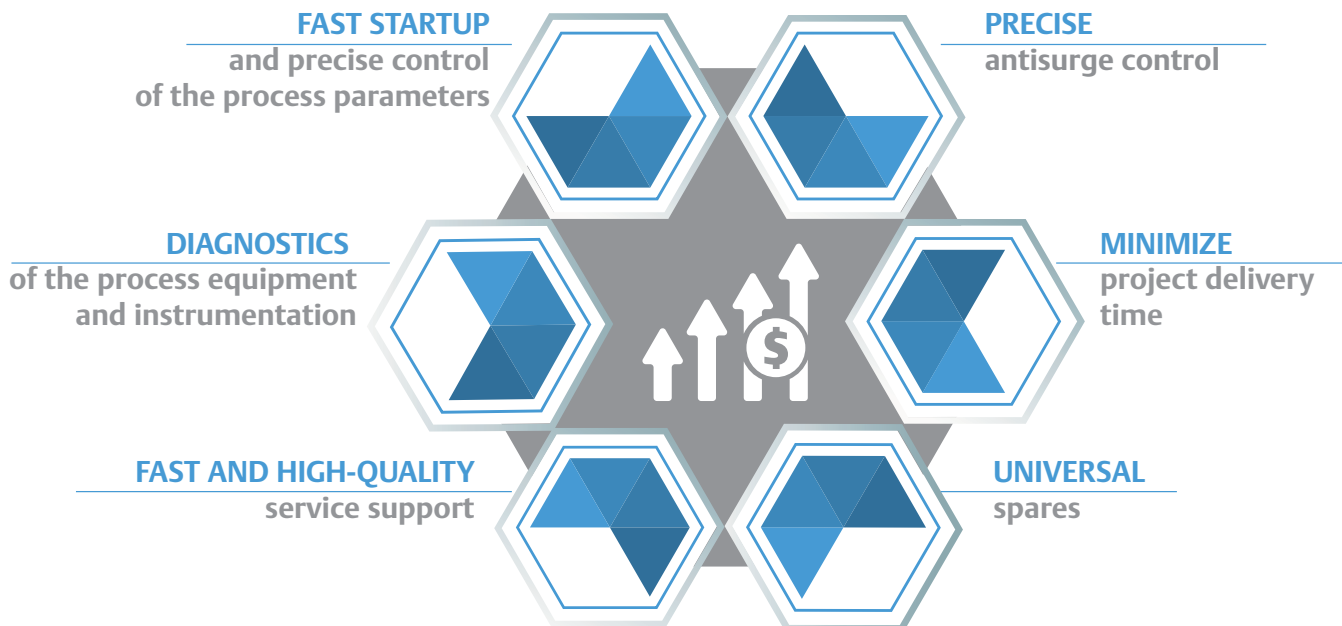
Increased compressor efficiency can result in fuel, steam or electricity savings as high as 25%!

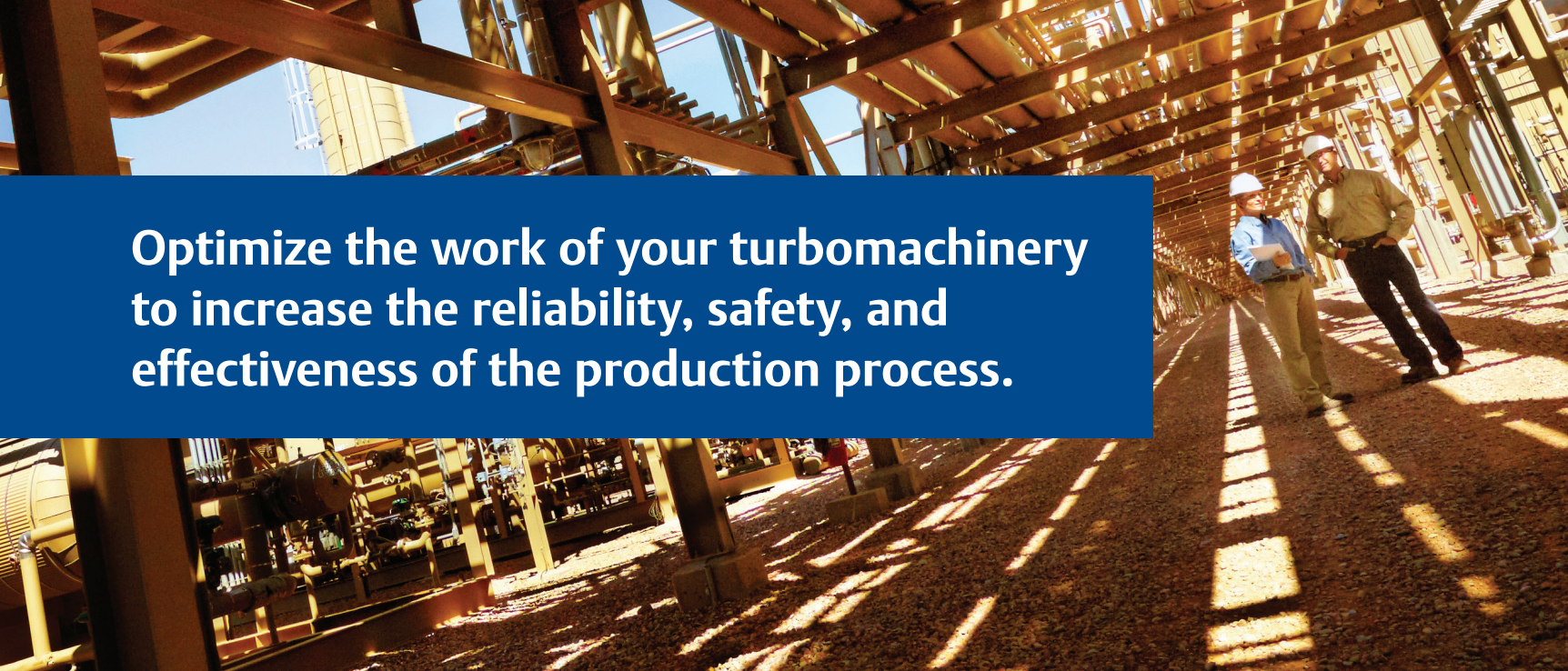
Total Economic Benefits

Economic benefits result from many factors:

- Faster unit startup
- Improved stability of the key process parameters while simultaneously minimizing consumed power
- Quicker service and support
- Universal spares for the control system and anti-surge system

Benefits from Emerson's compressor control offering go far beyond savings of consumed power. The solution from Emerson includes: better service and support for keeping the system operating at peak performance, integration of all components into the familiar DeltaV environment, ability to include machinery condition monitoring, high-performance specially designed anti-surge valves, market leading sensors which need only minimal calibration, transmitters with advanced diagnostics. Together, the solution represents the best on the market to achieve minimum total cost of ownership.





**Optimize the work of your turbomachinery
to increase the reliability, safety, and
effectiveness of the production process.**

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