



White Paper

S&C Turbomachinery Control Solutions for the Honeywell Experion[®] PKS Platform

Boris Pusin



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Introduction

Statistics & Control, Inc., (S&C) has been providing advanced turbomachinery control solutions on Honeywell systems for projects in Eastern Europe since 2008, steadily increasing its presence in the worldwide market. In October 2011, S&C and Honeywell formalized their relationship by signing a master service agreement for S&C to provide turbomachinery control solutions on Honeywell Experion[®] PKS platforms.

Currently, 24 units operating under the control of S&C’s applications built for the Honeywell platform have been commissioned, while another 13 units are in the process of being commissioned this year. Based on the number of fully operational units in the field, S&C can confidently say that the execution speed and power of the Honeywell Experion PKS controllers are more than sufficient to fulfill the required control and safety functions for even the most challenging turbomachinery applications.

All of S&C’s modules developed for the Honeywell platform use specific S&C faceplates and detail displays that are designed in the native Honeywell format but that are modified to accommodate S&C application functions. This design allows operators to quickly recognize data and learn configuration and operation techniques. Modules can be configured via the detail displays and controlled from the faceplate. Examples of specific module detail displays are provided throughout this paper.

Turbomachinery Control Modules

S&C provides a number of turbomachinery control applications that include—but are not limited to—Surge Prevention, Steam Turbine, Gas Turbine, Capacity, Master, and Power Generation Control. S&C’s turbomachinery control solutions may be used with a variety of the Experion PKS controllers, such as C200, C300, and C300-20. These control solutions have also been developed for different Experion PKS software releases, including R2XX, R3XX, and R4XX.

In release R4XX with the introduction of the custom algorithm block (CAB) framework, Honeywell allowed solution providers to create blocks inside the standard software package using high-level programming languages. With this opportunity, S&C was able to simplify the control modules, resulting in a more streamlined workspace. Figure 1 illustrates the complexity of the Surge Prevention Control Module in R3XX and the same module in R4XX.

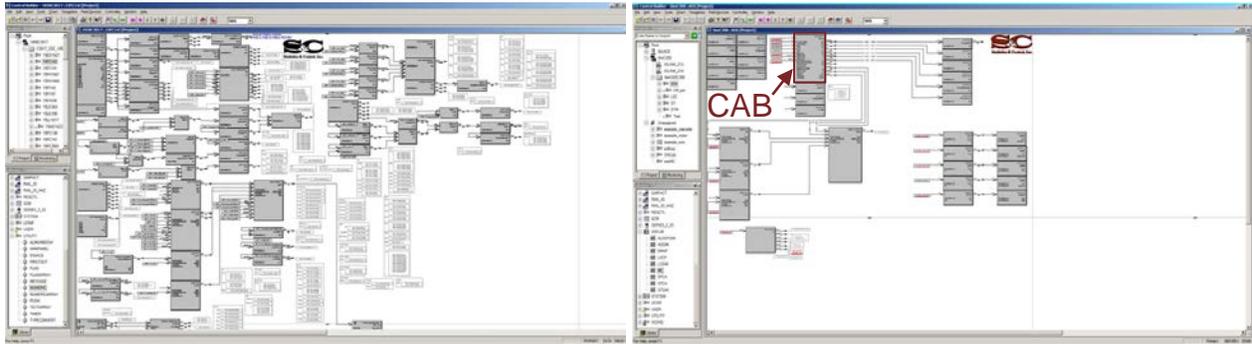


Figure 1. Surge prevention control module in R3XX (left) and in R4XX (right)

Surge Prevention Control

The primary function of S&C's Surge Prevention Control Module is to control gas flow through a compressor to prevent surge, avoiding potential equipment damage and process upsets. When the program detects that process conditions are approaching surge, the application opens and throttles the surge control valve to recycle (or vent) the downstream gas, preventing the compressor from experiencing surge. Figure 2 shows an example of the Main detail display.

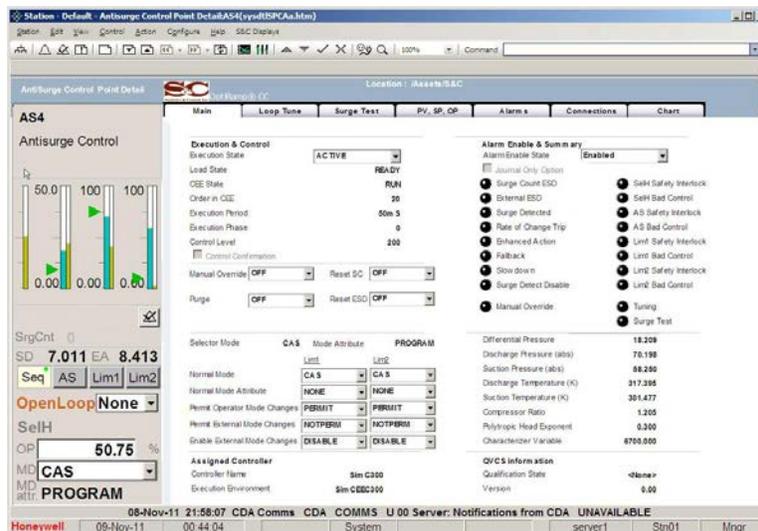


Figure 2. Main detail display

A number of factors must be accounted for while predicting how close a compressor is operating to surge conditions. The conditions at which surge will occur are a function of the mechanical

design of the compressor and process piping as well as the compression ratio, compressor speed, and gas composition.

Opening and closing the surge control valve at the optimal time, rate, and amount is a delicate balance and a complex function. If the valve is opened too liberally, surge is avoided, but energy is needlessly wasted. Conversely, if the control is too conservative, energy may be conserved, but surge may also occur. S&C incorporates two levels of PID control (Surge Control and Enhanced Surge Control) to act at exactly the right time and by the right amount for maximum operating envelope and reliable protection. Furthermore, in the event that a surge event occurs due to a process upset, the program automatically increases the safety margin to prevent a second event and sends an alarm to notify operators.

S&C's surge control can be calibrated according to the manufacturer's specifications and compressor maps or through field testing to determine true installed compressor performance and surge characteristics. The application simplifies calibration for the field engineers by recording surge events and conditions and by automatically defining parameters. An ActiveX dynamic compressor performance map can be displayed throughout the DCS network HMIs.

While S&C has many experiences providing surge control on a variety of units, one highlighted project is with the KINEF oil refinery (previously named the Kirishi oil refinery). This refinery is based in Kirishi, Leningrad Oblast, Russia, and is the largest refinery in northwestern Russia.

From 2008 to 2012, S&C was contracted and successfully engineered and commissioned surge and process control for various process units, including a gas fractionation unit (GFU) and a number of compressors in a hydrotreatment units, using the Honeywell Experion PKS platform. Additionally, for the newly built hydrocracking unit, S&C provided surge and capacity control for eight Atlas Copco air and nitrogen compressors.

In the GFU, while the existing surge control application protected the wet gas compressors from surge, the system had operated for years with partially opened recycle control valves. S&C's integrated control solution, in addition to surge control and bumpless transfer between the two compressors, created significant cost savings by successfully and completely closing the recycle valves.

In one hydrotreatment unit, there was an additional level of complexity. One of the electric motor-driven compressors was equipped with a variable frequency gearbox, which enables operators to control compressor speed by changing the set point in the Capacity Control Module.

The Surge Prevention Control Modules not only safely protect the compressors against surge but also work in conjunction with the Capacity Control Module to provide the plant more stable and reliable process control by flawlessly performing bumpless transfer between compressors, avoiding process disturbances and costly shutdowns.

Steam Turbine Control

S&C's Steam Turbine Control Module includes specifically designed function blocks and logic to start, stop, control, and protect steam turbines driving industrial equipment and electrical generators. Algorithms process multiple PID loops to control valve position to maintain the requested turbine speed set point based on the speed control, load control, load rejection protection, flow characterization, pre-warming, protective system testing, overspeed protection, and valve testing. Figure 3 shows an example of the module Loop Tune detail display.

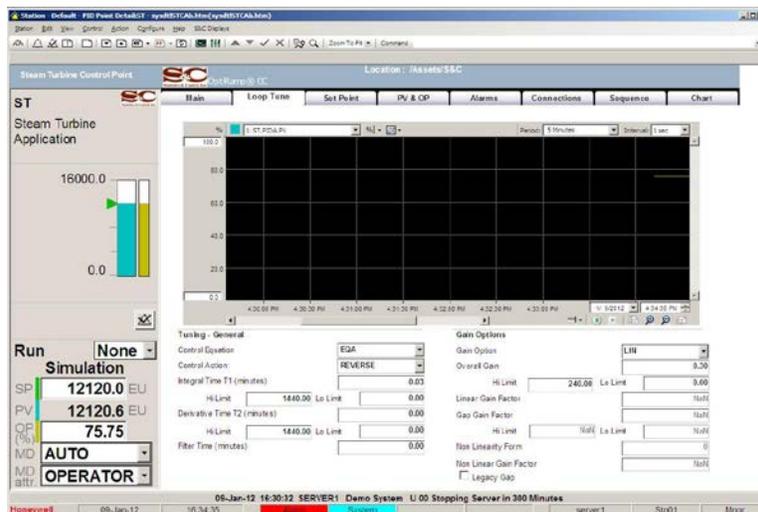


Figure 3. Loop tune detail display

For extraction turbines with high- and low-pressure stages, S&C's control system maintains turbine speed/power and extraction pressure/flow by regulating the positions of the steam supply and extraction valves. To stabilize the process interaction between these two valves, algorithms calculate this control action combination based on a turbine performance map.

A project that exemplifies S&C's Steam Turbine Control Module is the Cherepovets "AZOT" Ammonia Plant, which is located in the Vologda region of Russia. This plant is among the largest Russian producers of ammonium nitrate and ammonium nitrogen fertilizers.

S&C's scope of work was upgrading controls on two steam turbine-driven compressors. The first unit is a synthesis gas compressor driven by a Mitsubishi steam turbine with steam extraction. A Woodward hydraulic actuator is used to position the steam valves for this unit. The second unit is a Russian-manufactured air compressor driven by a steam turbine. The hydraulic speed control system on this unit was maintenance intensive and provided very imprecise control.

S&C was required to use Honeywell C300-20 controllers on both turbines to provide steam turbine and extraction control, process control, surge control, and turnkey start-up and commissioning services as well as with replacing the hydraulic control system with electromechanical for the second unit.

Because the first unit uses the steam extraction turbine as a drive, two control variables must be maintained: compressor speed and steam pressure in the extraction. Therefore, the turbine is equipped with two control valves that must be simultaneously modulated to achieve balance and control. The Speed Control and Extraction Control Modules are used to achieve this goal. Honeywell's Speed Protection Module (SPM) was used to accept and convert the frequency signal from the speed sensors for control application use. The Servo Valve Position Module (SVPM) was used to drive the coils of the Woodward actuator.

For the second unit, the hydraulic speed governor was replaced with an Exlar electromechanical actuator (see Figure 4). The new design measures turbine speed through magnetic pickups, for which mounting hardware also needed to be engineered, fabricated, and installed. A Honeywell I/O Speed Protection Module (SPM) was used to accept and convert the frequency signal from the speed sensors for control application use.

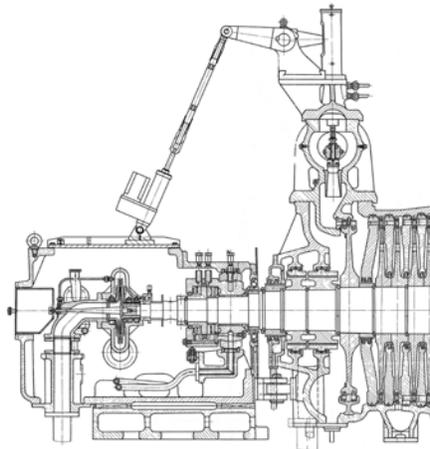


Figure 4. Steam turbine with Exlar actuator

Even with fluctuations in steam supply pressure, the new control system for the second unit has achieved turbine speed control accuracy of ± 1 RPM. Removing the maintenance-intensive hydraulic system eliminated the error that resulted from erosion and build-up on mechanical parts due to poor oil quality and cleanliness.

The design has been completed for the entire train, and the Steam Turbine and Extraction and Process Control Modules have been commissioned; the Surge Prevention Control Module is planned to be commissioned at the next turnaround. S&C's applications at Cherepovets were customized for C300-20, which was the first project in Russia completed using this technology.

Gas Turbine Control

S&C's Gas Turbine Control Module includes multiple PID loops to accurately position the fuel control valve, guide vanes, and/or nozzles to maintain the requested power turbine speed set point. The requested set point is based on the high- or low-pressure shaft speed, exhaust gas temperature, compressor discharge pressure, power turbine speed, fuel control valve minimum/maximum position, and acceleration/deceleration limits. Multiple speed sensor inputs

can be used to generate a single value for error term calculation to help ensure reliable and accurate operation within safety tolerances. The goal is to control gas turbines according to manufacturer specifications and customer best practices.

The Gas Turbine Control Module solution is typically integrated into the total train control system, which eliminates the need for a dedicated fuel control processor, rack, and power supply. This approach results in increased train control system availability and reliability as well as reduced system costs.

Capacity Control

The primary function of S&C's Capacity Control Module is to maintain a compressor's process variable through appropriate loading. This module controls the primary process variable (compressor suction or discharge pressure or flow through compressor) with two limiting PIDs. Limiting variables can be most any variable, including compressor motor current, compressor suction or discharge pressure, or flow through compressor. Figure 5 shows an example of the module Connections detail display.

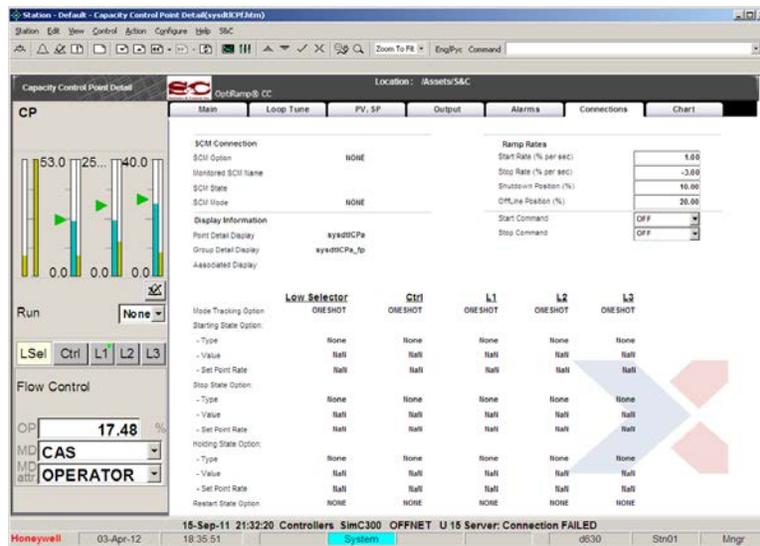


Figure 5. Connections detail display

Master Control

For stations with multiple units—whether in series, parallel, or a combination—the Master Control Module is used to control and distribute load. The Master Control Module has two primary functions: load sharing and load balancing.

Load sharing, depending on the unit type, is accomplished by controlling the throttle valve or guide vane position for compressor units or by controlling the speed for steam and gas turbines through interaction with the Capacity Control, Speed, and Fuel Gas Control Modules. Figure 6 illustrates an example of the module Load Sharing detail display.

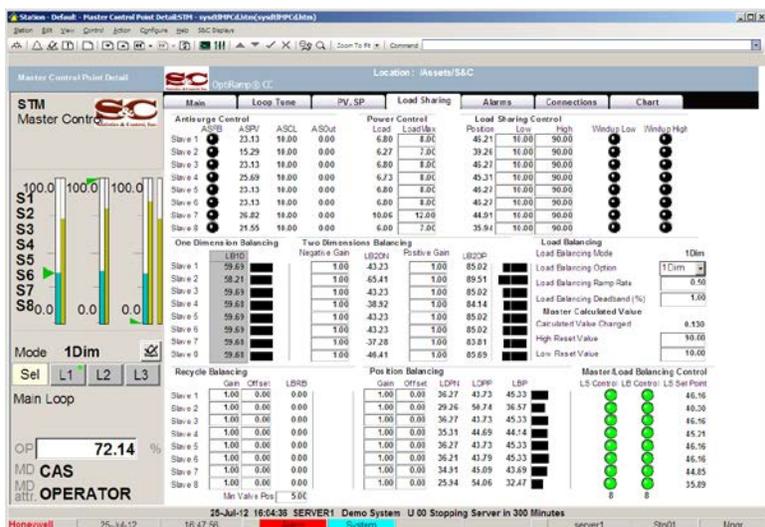


Figure 6. Load sharing detail display

Load balancing, which is separate from load sharing, is an optimization strategy. Load balancing strives to maintain the load balancing criteria for all units. Options for load balancing are one-dimension, two-dimension, position, and recycle balancing.

Power Generation Control

The overall application used for power generation control is S&C's Power Management System (PMS), which uses a combination of control applications to balance active and reactive power among all operating units and transformers, provide precise control of active and reactive power exchange with the national grid, and conserve energy through load sharing.

The Power Management System provides multiple layers of control. The Active Power/Frequency Control (P/F) Module (illustrated in Figure 7) is used to limit active power exchange with the grid, ensure proportional load (MW) sharing among generators, and control frequency in islanded conditions.

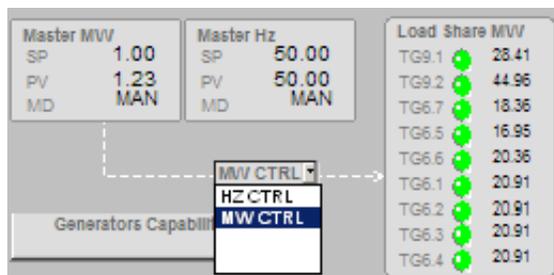


Figure 7. Active power/frequency control modules

If a problem were to occur causing the plant to be islanded from the grid, the Frequency Master Control Module within the PMS maintains frequency. This controller may be manually or

automatically switched in case of isolation. Additionally, S&C provides logic to control frequency in case a substation is isolated from the rest of the plant.

The Reactive Power/Voltage Control (Q/V) Modules (see Figure 8) regulate bus bar voltage, ensure proportional reactive power (MVAR) sharing among generators and transformers, and limit reactive power exchange with the grid.

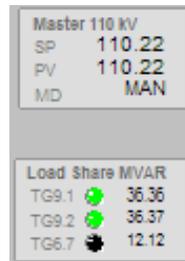


Figure 8. Reactive power/voltage control modules

The PMS is also used to control transformers as well as unit active and reactive power performance, as illustrated in Figure 9.

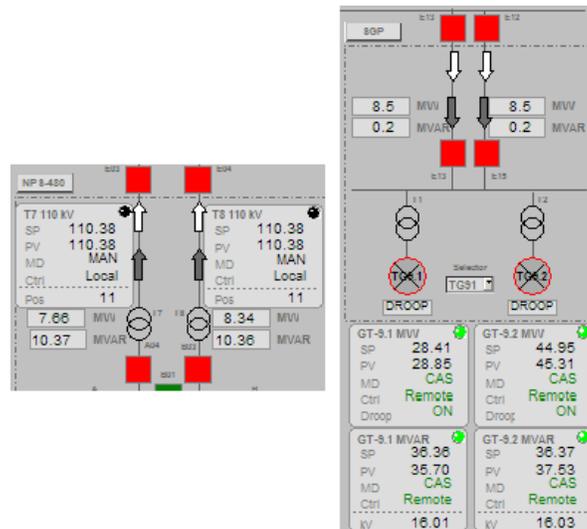


Figure 9. PMS transformer control (left) and unit active/reactive power control (right)

An example project is the Kazakhstan-based Tengizchevroil (commonly referred to as Tengiz), which produces four petroleum-based products for domestic and foreign markets: crude oil, liquid petroleum gas, sulfur, and dry gas.

The Tengiz facility has three electrical generation substations for powering the refining operations. The first substation has four GE Frame 6 gas turbine-driven generators at 40 MW each. The second substation has three GE Frame 6 gas turbine-driven generators at 40 MW each. The third substation has two GE Frame 9 gas turbine-driven generators at 120 MW each. These

nine units are connected to buses of varying voltages (10 kV, 35 kV, and 110 kV) via respective transformers.

Past incidents in the power plants, such as shutdowns and trips, severely and negatively impacted the oil production facility in terms of lost oil and gas production and increased gas flaring. S&C was contracted to develop and commission a PMS to provide regulatory control, monitor spinning reserves, and maintain zero exchange with the national grid.

S&C's PMS applications were seamlessly integrated into the Honeywell Experion platform at Tengiz using four redundant C300 controllers. The PMS has helped save Tengiz energy, time, and money.

OptiRamp® Integration

While S&C's turbomachinery control solutions are comprehensive and highly flexible, the ability to interface these solutions with the *OptiRamp*® software truly sets S&C apart from other turbomachinery solution providers. *OptiRamp* is an artificial intelligence system for process modeling, conceptual design, real-time and off-line simulation, closed-loop optimization, financial validation, scheduling, and performance monitoring. The ultimate goal is to provide control actions that maximize current and future process efficiency.

When *OptiRamp* is combined with S&C's turbomachinery control solutions, it is not only used as a visualization tool; it is also a very powerful dynamic simulation tool that allows the control strategy to be tested prior to commissioning. Additionally, *OptiRamp* can be used as an Operator Training Simulator (OTS) if it is connected to PKS controllers in a simulation environment, which eliminates the need for a separate hand-on OTS.

Visualization has been important for multiple projects already discussed. At the KINEF oil refinery, S&C installed *OptiRamp* software to provide compressor map visualizations (see Figure 10) to monitor the operating point and compressor reserves.

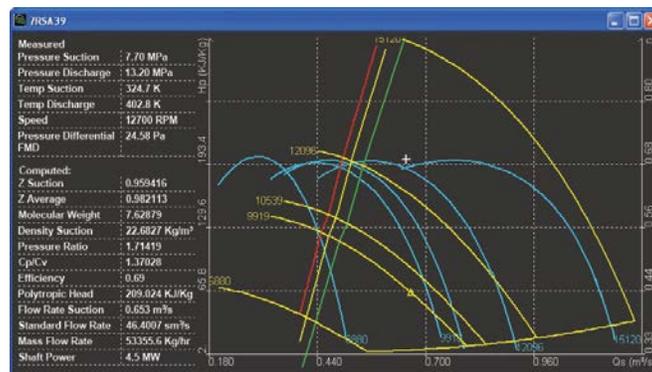


Figure 10. Compressor map visualization

At the Cherepovets "AZOT" Ammonia Plant, S&C incorporated *OptiRamp* technology with its Steam Turbine Control Module to create a speed control and extraction map (see Figure 11) that

precisely calculates both valve positions based on all related process variables. S&C also provided an ActiveX display for HMI visualization of this map based on real-time measured conditions and turbine speed.



Figure 11. Extraction map visualization

For the Tengiz project, S&C provided *OptiRamp* ActiveX generator map displays that visualize generator reserves, current operating point, and operating limits for each unit. These limits are supplied to the Honeywell control system to be used as limiting variables for the unit controllers. Figure 12 illustrates example of a generator capability map and a voltage vs. frequency map.

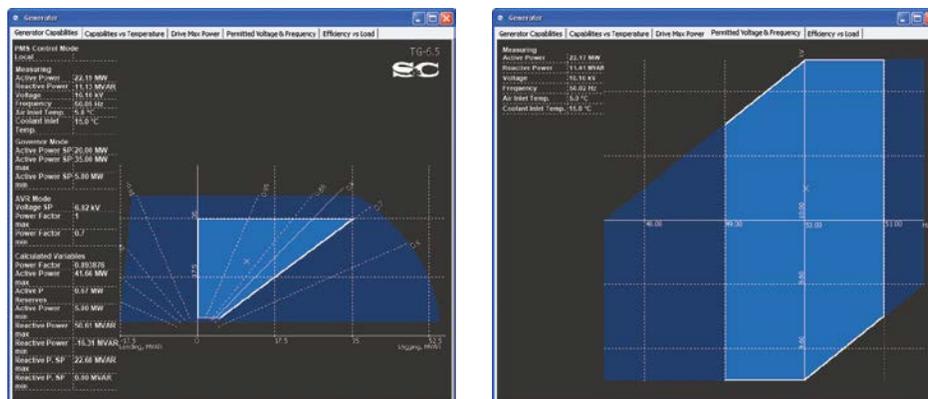


Figure 12. Generator capability map (left) and voltage vs. frequency map (right)

Additionally, S&C's *OptiRamp* PMS solution included a dynamic simulation of the entire Tengiz microgrid and all of the power generating units. The *OptiRamp* real-time model is interfaced with Honeywell HMIs housed in the plant training center, which reduces training time and enables operators to practice "what if" scenarios.

Conclusion

S&C has a strong heritage of designing and supplying advanced control solutions for a wide range of industries in order to provide robust, reliable, and efficient control. The combination of



S&C's customizable turbomachinery and advanced process control solutions with the Honeywell platform leads to unified hardware and software platforms throughout the entire enterprise. Ultimately, S&C's solutions are seamlessly integrated into the overall control system, decreasing maintenance and personnel training costs.



About Statistics & Control, Inc.

S&C—an engineering consulting and technology company headquartered in West Des Moines, IA—solves complex challenges for customers through its unique technology and its highly seasoned team of professionals. The company has a global portfolio spanning the energy, oil and gas, utility, and digital oil field industry sectors. S&C provides clients with turbomachinery control solutions that easily integrate with the existing system as well as *OptiRamp*[®] solutions, which focus on process and power analytics to optimize processes and, in turn, reduce costs and increase reliability. S&C also provides consulting, dynamic system studies, modeling, automation, training and OTS, and support services.

Statistics & Control, Inc.
4401 Westown Pkwy, Suite 124
West Des Moines, IA 50266 USA
Phone: 1.515.267.8700
Fax: 1.515.267.8701