



MODERNIZING TURBO-MACHINERY AND AUXILIARY CONTROL SYSTEMS AT A MIDSTREAM GAS PLANT

INTRODUCTION

Over the years Tarco has been involved in many turbomachinery and auxiliary system upgrades for our clients seeking an alternative to an OEM service or costly replacements. Requirements for faster turnarounds, higher uptimes, and improved safety, have made properly executed upgrades increasingly pressing. In this paper we detail one such project that provided customer a modern system, and all its related benefits, while extending the life of existing equipment. A Midstream company upgraded the turbine and compressor control systems at their Texas Gas processing plant.

These upgrades included replacing the original OEM controls on two GE LM2500 turbines, and two Demag/Delaval 4 section centrifugal compressors to increase reliability, efficiency, simplify operation and streamline maintenance and support requirements. This paper describes the process used to qualify the need to modernize the controls replacement control systems assessment, and the turnkey vendor evaluation and selection. Project scope development, implementation, results and benefits derived from the system upgrades are also discussed. The plant downtime for the whole project was minimized to 10 days and this included the successful commissioning of the plant. The project significantly improved the overall plant availability and reliability.

With over 60 plants, 10 fractionating facilities and tens of thousands of miles of gathering and transmission pipeline, the company is one of the top natural gas gatherers and processors in the United States. High reliability and availability of operating plants are paramount to the company.

Tarco was founded in 1997 providing innovative industrial automation solutions and services to the Oil & Gas industry, and has its head office in Calgary, Alberta. Tarco has its own brand of rotating equipment controls (over 300 installed worldwide), and also provides services for electrical & instrumentation (design & installation), field service (24/7 support/troubleshooting, training, LTSA, PM/inspections) and full EPCM services.

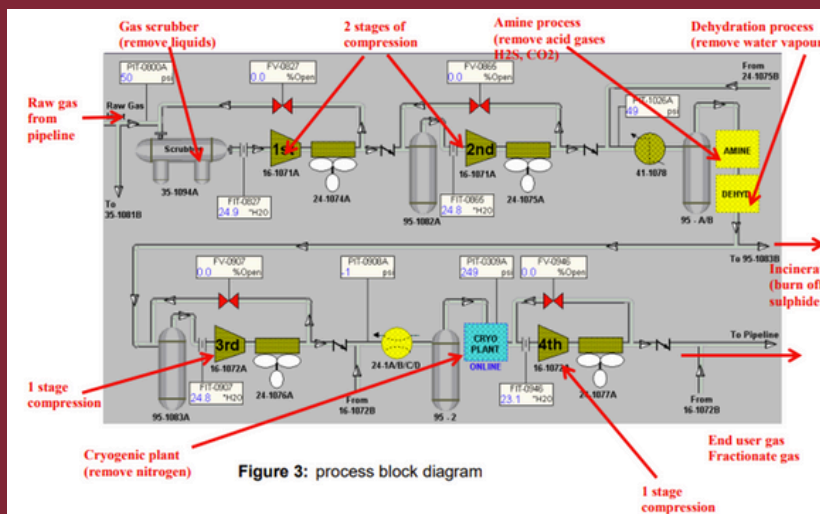
The processing plant extracts NGL's (natural gas liquids) from raw natural gas that has been pumped from the well head. The purpose of this process is to extract and deliver through pipeline facilities NGL liquids, (ethane, propane, butane etc) and produce standard quality natural gas for domestic or business end-users. The raw gas is classed as 'sour' gas containing hydrogen sulfides. The gross capacity of the plant is over 160 MMcf/day. This facility has two aero-derivative GE LM2500 turbine compressor packages that were installed in 1995, since when the units had been running virtually non-stop through that time. The controls were the original OEM systems. Their reliability was decreasing at an alarming rate and correspondingly the plant's ability to support these OEM legacy systems had become both expensive and challenging as existing spares were either old, dwindling in numbers or no longer available.

PROCESSES AND MAJOR EQUIPMENT WITHIN THE FACILITY

The facility used the following major hardware components to move the pipeline gases through the process described figure 3.

- 2 x Stuart & Stevenson LM2500 SAC gas turbine Packages (20MW Output)
- 2 x Demag / Delaval 4 section Centrifugal Compressors
- Compressor valve train and filter, separator, cooler and scrubber systems
- Original OEM control systems for the turbine and compressor units (GE Fanuc Series 90-70 PLC, Bentley Nevada vibration monitoring system, Wilson Fire & Gas Detection and Suppression system, and six CCC Surge controllers)

The two LM2500 gas turbine-driven compressor units operate in parallel at the gas plant. Each gas turbine drives three compressors through a gearbox. One compressor set (2 stages) is used for raw gas treatment (amine and dehydration processes), the second compressor set is used for residue/treated gas (and cryogenic process) and the third compressor set is used for the sales (residue) gas. The basic process description is shown in the flow diagram below. The various original controlling and monitoring systems are included.



MAJOR CHALLENGES FACED AT THE PLANT

The plant is a significant contributor to the company's financial goals. Downtime or process errors have a cost impact but also an emissions and brand impact due to the ever increasing focus on venting and flaring of natural gas. Due to the complexity of the old system, and plant personnel turnover, the client had difficulty maintaining and troubleshooting the system. This was made more difficult due to the multiple vendors involved before the upgrade.

Oil reserves are curtailed if these key pieces of equipment are not in operation. Reliability around other processes in the plant were being negatively affected by the inconsistent runtime on the two units. The facility had experienced numerous shutdowns due to PLC failures, some due to single CPU's or locked up components, others due to complete failure. Such events could happen during normal operations and/or maintenance. The facility sought a redundancy option as part of the upgrade to reduce this issue.

The gas control valve also suffered from reliability issues such as sticking and hydraulic actuator failures. The turbine starts were inconsistent, especially in cold weather when the oil was cool.



The hydraulic valves did not have reliable position feedback, preventing the operators from diagnosing problems accurately when the plant went down resulting in large delays for troubleshooting.

The gas turbines at the plant operate NOx control water injection. Similar to the issues with the fuel valve, the water injection valve had inconsistent hydraulic actuator control and unreliable feedback. The water valve would often enter an oscillating condition that de-stabilized the engine and caused a plant shutdown.

Starting from a depressurized state was a complex process for the plant operators. With four compressors for each drivetrain, the original package required the operators to move between four different operating systems to monitor and control the valve status, pressures, timer and sequencing. When issues arose, the alarming would only point to a high-level sequence fail, there was no drill down to single point-of-failure, which could have been caused by any one of several valves or pressure points.

PROJECT DESCRIPTION

The main requirement of the project was plant modernization with a goal of improving overall plant performance on an economic basis by increasing uptime, thereby increasing plant throughput and reducing operating and maintenance costs. Due to the importance of the plant to the company's operations, a tight 10-day window was required by the facility to minimize plant downtime and prevent major disruptions. The client requested all of the involved vendors to site to trouble shoot system problems. After resolving a way forward with their issues on the old system, the client requested high level proposals for a system upgrade. The company would require 24/7 site coverage for the project with the same personnel on demand. The project started with an initial detailed site survey to fully understand the existing equipment and structures. From this visit the project planning/cost/scheduling and basic engineering (FEED) was completed; Tarco proposed delivery of a complete turnkey project.

After aware, a complete engineering design commenced, which detailed construction deliverables, procurement of site materials, quality planning/control and testing. The collection of existing drawings from the site visit was updated with the modifications from the design phase. The site survey and detailed discussions with customer, and collaborative approach to the projects was critical to achieving the tight turnaround window successfully.

PROJECT SCOPE

The scope of this project involved the control system upgrade for the two turbine compressor packages. Both the existing turbine control system and driven compressor control systems were replaced with a motiv® Tarco control system (TCS). A new fire and gas panel was installed for protection of the turbine enclosure and was fully integrated into the turbine control system. Details of the upgrade included:

- Replacement turbine fuel control panels and system using the latest redundant off-the-shelf PLC and HMI (to include fuel Control, Sequencing, Alarm and First Out, Timers, Signal conditioning, Lockout Display, Diagnostic tools, Backup over speed)
- Replacement of the triple stage anti surge compressor controllers to a new redundant PLC system
- New control building
- New replacement fire & gas panel fully integrated into the TCS
- Interfacing the new turbine control system to DCS
- Replacement control valves (water & fuel)
- Selection and conversion of existing field devices and installation of new instrumentation to support the new redundant control system
- Upgrade and integration (with new TCS) of the existing vibration system
- Installation of new VSV position feedback
- Installation of UPS equipment, cable raceways, trays and supports from new Control Room through to packaged equipment marshaling locations and through to end devices and new remote I/O panels (in package)
- Installation of turbine simulator and new equipment training program for plant staff competency

The two original hydraulic fuel and combustion NOx water valves for the turbine control were replaced with highly robust electronic Woodward metering valves (CS16 and 3151A respectively). This improves the control, operability and ensures extended operation of the gas turbine assets. Also, all hydraulic accessory pumps and associated hoses were eliminated by this installation. The driver contains fault detection circuitry which provides the status of the 4–20 mA interface, position controller, driver, and feedback to the shutdown logic. The existing LM2500 turbines used hydraulic VSV (open loop) air flow control but did not include actual VSV position feedback to the turbine control system. These systems are optimized for performance efficiency (i.e power and heat rate) at high power and turbine surge control at lower powers. Unfortunately, fouling on the compressor caused the engine to be pushed into a surge/rotating stall condition. As there was no VSV feedback this went undetected resulting in compressor damage. The engine had to be removed and sent off site for repair. A LVDT was installed to provide position feedback for the VSVs and the HMI had a screen added to watch and alarm against the VSV schedule. The existing Bentley Nevada 3500 vibration monitoring systems (for the turbine and driven compressor units) was relocated to the new TCS cabinets located in the new turbine control building. Vibration monitoring signals were integrated into the motiv TCS system, Foxboro DCS system & the newly developed turbine HMI system. The TCS was integrated into the DCS because there is instrumentation in the TCS system that is not available to the DCS. It also allows the remote alarm systems (paggers, cell phones etc.) to flow through to the operators. The plant systems were to be designed in a redundant fashion so that any loss of one component would not cause the turbine to shut down. The Allen Bradley PLC controller had two systems installed (one live and one backup with a dual communications card), dual power supplies were added and any instrumentation associated with package/ balance of plant control was made redundant.

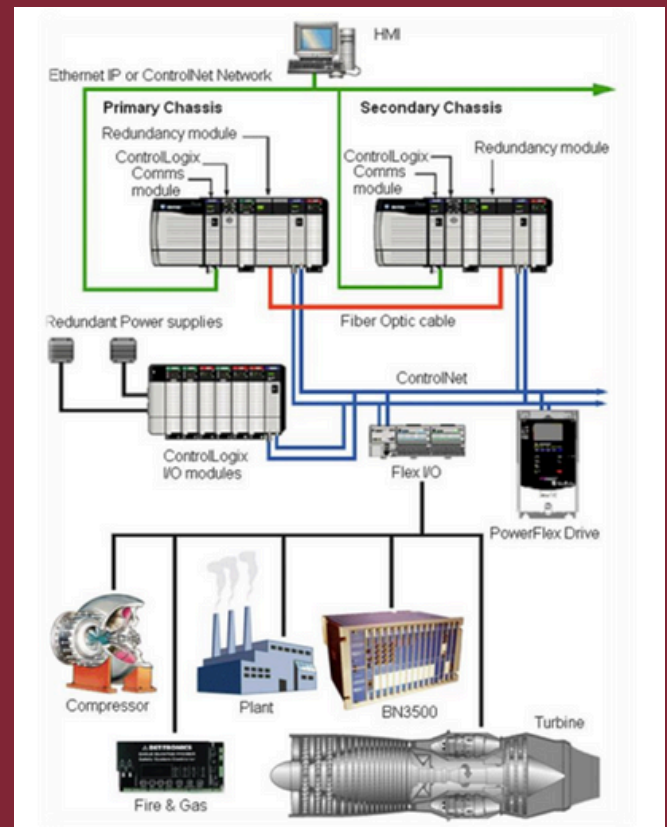


Figure 4: Basic Control System Structure

REPLACEMENT CONTROL SYSTEM

The new control system had a huge advantage over the legacy system as it tied together the separate control and alarming systems and hardware in the plant. As discussed above, the new system had to combine the fire and gas, vibration, original turbine fuel control, compressor surge and other plant alarming systems. Not only were many of the instruments doubled for redundancy but the control PLC itself also had an identical backup unit installed with UPS systems. The system was designed so that the loss of a single instrument, PLC, single power supply or single communications card would not cause a unit to shut down.

Instrumentation

The new control system had to integrate was over 1300 devices, many of these being added to provide full system redundancy. The system was designed to be fault tolerant without comprising safety or equipment protection. I/O list with included as examples:

- Digital inputs: operator inputs (increase/decrease speed) and various pumps/valves conditions (on/off).
- Digital outputs: turbine running conditions (i.e. start sequence), on/off demands for various equipment (pumps/valves/igniters), reset and alarm/shutdown conditions.
- Analog inputs: combustor flame sensors, thermocouples, RTD's, frequency sensors, pressures etc.
- Analog outputs: turbine fuel/water valve demand & recycle valve demand for the driven compressors.

ISA tagging style convention was followed for the I/O, with all alarm descriptions having the proper ISA tag names showing up in the descriptions.

CONTROL PHILOSOPHY

There are many governors and limits (such as exhaust gas temperature, transient maneuvering or starting fuel flow governors) that act together to directly determine the output power and maintain stability of the gas turbine and driven compressors. The control valve position outputs for each governor are fed to low-high-low signal select buses where the 'winning' signal is passed out of the control system as valve position demands, the 3 main components being:

- Turbine control – controls fuel, water and VSV valves, ensuring turbine limits are not exceeded
- Surge control – controls the recycle valve on each compressor, both individually and as a set to ensure that surge conditions do not occur and provide overall load sharing
- Package Control – takes care of everything else (i.e. starting, stopping, loading), auxiliary equipment (such as supply lube oil system) and decides when to enable or disable the turbine and surge control

HUMAN-MACHINE-INTERFACE (HMI)

Two PanelView Plus HMIs were installed to replace the existing system. The goal was to keep as much of the layout similar for staff familiarity but improve key screens so that operators did not have to flip back and forth to perform a single function. For example, performing the startup of a turbine unit had all the parameters required for that procedure. Allen Bradley Factory Talk View software platform was used and various performance displays (efficiencies, heat rate and power output) were included. Navigation through the HMI screens was improved with a two-line selection bar (top row buttons for main headings and bottom row buttons for sub-categories).

Overview	Turbine	Compressor	Process	Start	Fire & Gas	Trending	Config	
Overview	Surge Maps	Raw Gas Seal	Residue Gas	Lube Console	Lube System	Bearings	Vibration	UNIT ESD

During the project, the compressor units were tested and mapped out to verify the surge margin characteristics. New compressor load sharing control was added which compared all the units and determined the one with lowest percentage from surge. The highest unit of the set would be trimmed back on speed to balance the whole train and allowing more gas flow through other units. This vastly improved overall operation but also added stability to the equipment that improved other running conditions, including starting.

TURBINE SIMULATOR

The improvement of plant operator understanding of the key facility assets was another of the main drivers for the project. For training and troubleshooting purposes, a unique solution was implemented at the plant to develop competency for existing and future plant operators and technicians. A simulator system was installed in the PLC system that could be used to demonstrate:

- Normal plant control system operation
- Control system response in abnormal conditions (e.g. what happens when a particular transmitter fails)
- System configuration testing (e.g. transmitter scaling, set point modification) of both the software and electrical systems
- Control system hardware troubleshooting

The software simulator drives every I/O point in the system. There are settings for automatic, hardware and manual modes:

- When in automatic, the I/O point responds in a typical running fashion.
- Hardware: the point is re-mapped to the simulator hardware, allowing testing and simulation using actual transmitters. For example, a technician can connect a transmitter to one of the analog input channels and calibrate the 4-20 device and configure its scaling and alarm set points from the display.
- Manual: when in manual, the operator can set the value (on/off or analog) to any value. This allows realistic training scenarios (limit switches which don't trip, analog values that decay). It also simulates exact duplication of actual events, allowing cross training of operator shifts from incidents that may occur in the plant. For example, if the ignitors are enabled, the fuel valve is open and there is fuel supply pressure then the simulator will increase the T5 temperatures to simulate ignition.

The set points (e.g. pressurizing timers) can also be changed to modify how the simulator works. The simulator alarm logger will display any errors in the system, such as input faults. The hardware portion of the simulator is used as a "hot" spare depot in addition to replicating each hardware circuit. This gives confidence that spare parts are at the correct firmware, revision level etc. It also allows realistic training, as the prints and circuits are the same as the main project. The system helps technicians become familiar with the operations of the actual unit without working on live equipment.

Both hardware and software allow testing of maintenance or training procedures on the simulator before implementing them on the live system, saving time by not having to start the unit from a de-pressurized state. This has since consequently prevented several shutdowns as operators and E&I technicians were able to practice a replacement of a defective part, involving jumpers and software with the simulator demonstrating procedure required to avoid shutting down. Without the simulator this would have resulted in a plant shut down, with an obvious downtime and cost implications

CONSTRUCTION AND COMMISSIONING

This plant turnaround was the largest in its history, with hundreds of other contractors cleaning, replacing and adding new vessels, piping, and other equipment. In addition to normal turn around activities, the exhaust collectors, stacks and one of the engines was replaced. This additional work in and around the area of the new control system demanded very detailed and flexible planning.



Installing the new electronic fuel valve



New field transmitters for the driven compressors



Newly installed cable raceways



New VSV feedback LVDT installed

The site coordination for the upgrade project was conducted by Tarco project management, organizing the manpower, logistics and materials supply to site. Prior to the main outage to minimize downtime, installation of the majority of the components (new cable, cable raceways, remote I/O panels) was undertaken, including the new control building which would house the main TCS panels and UPS systems.

Approximately 30,000 feet of cable, cable raceways, trays and supports were installed between the packaged equipment end devices and the new Control Room. Over 80 new field instrumentation devices were installed, all critical field transmitters were replaced with new devices with redundant transmitters added. The transmitters were pre-commissioned prior to shut down. The new fuel and NOx water valves with replacement piping spools were installed, having been pre-fabricated and fully tested before the outage to ensure that fitment during the outage was seamless.

The factory acceptance testing (FAT) was successfully completed in Calgary in December of the year prior to the shutdown. All panels were connected live with a running simulation model that mimicked the plant and turbine operation, allowing full testing of every control loop and operating system (existing and new). In April, the plant was shut down for commencement of the project construction and installation phase. Within 10 days, the demolitions and removal of old equipment had been completed, and the relocation of existing or new control system hardware began (e.g. fire system, BN3500/3300 vibration panels, critical control devices), as well as the install and integration of the new Turbine Control Panels and consoles.

Using the turbine simulator panel, training for the new control system was conducted for the plant operators during the facility down period. Once the plant was brought back online, the plant personnel were very familiar with the new control system and comfortable with plant operations.

The site acceptance testing (SAT) commenced with full function testing and verification of all I/O devices (full end-to-end checks), turbine/drive train equipment operation and validation of the system alarms/shutdowns and redundancy. This was proven through the HMI screens with customer participation. Full certification documentation was signed off and delivered to the client for each test which included technicians involved, equipment serial numbers, tests performed and testing equipment certification. Instruments which were not replaced during pre-commissioning were re-connected to the new control system and also tested.

The commissioning phase was a challenging aspect of the project due to the many plant changes that were concurrently made. Instead of being able to start, test and validate the turbines in isolation (the usual process), as soon as the first turbine was safely available it was used to pressurize/purge and start the plant. Once the required plant equipment was powered up by the first turbine, the second unit was started and commissioned. With enough fuel/pressure and plant equipment running, this enabled the full commissioning of the project to be completed. The plant successfully restarted operations again, meeting the scheduled 10 day outage, and the facility hasn't had a shutdown since related to the control system reliability or package operational instabilities.

CONCLUSIONS

The upgraded facility control system has shown a marked improvement in the reliability and availability of the plant. The project was completed within the 10-day schedule, ensuring that the plant downtime was kept to a minimum. The main benefits of this project are summarized as follows:

Improved Reliability and Operability With added operation controllers the compressors can handle far more plant upsets without having the engine shutdown. These controllers also allow additional recycling, keeping sub-parts of the plant operating far longer in upset conditions.

Surge control integrated into the control system has allowed clearer and better tuning without adding risk to the compressors. This has allowed for one button start and loading of the turbines, greatly increasing reliability and speed of coming to full power after a shutdown. This benefit is compounded, as starting operations are only done when operator's attention is needed in other parts of the plant as well.

Reliability benefits equate back to better throughput, less flaring and overall improved customer satisfaction. Runtime on these two units has been close 100% since the control system was installed and commissioned. This is in comparison to 96% to 98% runtime before the upgrade (160mmcf/d X 98% = 156.8mmcf/d, LPO = 3.2mmcf/d or 11680mmcf/yr). The NOX emissions reduction has kept the plant within the state mandated limits, and reduction in flaring due to the tripping offline has seen the same reduction as the increase in runtime percentage. The new system is far more cost effective, as the common use of PLC I/O cards rather than separate systems.

Better Troubleshooting The operator's visibility of the plant equipment has been improved. For example, by installing differential pressure switch transmitters between each compressor the operators can determine any issues on a component level. With the original system, if a valve sequence failed the challenge was identifying the root cause among several valves or pressure points failing. New system alarms point to the exact device (valve, switch etc.)

Common platform – The new system brings everything into a common platform with better HMI's. Previously, the client could not see load sharing or compressor information. New process controls added, and placed all of the information/alarms on one screen providing better access to the system (process overrides on recycle valves.)

Training and Other Plant personnel are trained on-site via the turbine simulator, providing a competency tool for staff, with improved troubleshooting knowledge. This also provides operators a safe method for testing hardware changes without the risk of tripping the facility. The open architecture philosophy of the control system will provide further improvements, such as the planned future turbo-expander and BMS projects at the site.

NOMENCLATURE

NGL	Natural gas liquids
TCS	Turbine control system
FAT	Factory acceptance test
SAT	Site acceptance test
HMI	Human-Machine-Interface
PLC	Programmable logic controller
NOX	Nitrous Oxides
UPS	Uninterruptable power supply
E&I	Electrical and Instrumentation
I/O	Input/Output
VSV	Variable stator vanes
LVDT	Linear variable displacement transducer
CPU	Central processing unit
OEM	Original equipment manufacturer
FEED	Front-end engineering design
SAC	Standard aero combustor
DCS	Distributed control system