Gas Turbine Control System Retrofits

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1. Abstract

This white paper reviews the need for undertaking Gas Turbine control system retrofits, how this might be considered together with the benefits that might be obtained. This paper also examines some of the typical arguments that can be made to determine whether such retrofits are appropriate and the technology that can be used.

2. Introduction

Over the past decade, the use of electronic and in particular digital control equipment has created a perfect storm for many users in managing their assets and installed equipment.

Whilst mechanical equipment can last for many years, control and instrumentation equipment has a limited lifespan before software or component obsolescence can make it increasingly difficult to support and maintain installed equipment.

Such obsolescence can be most significant for technology based companies where the critical technology used is part of their service or production. It may also mean that they can no longer be competitive within the marketplace.

Obsolescence can also mean that companies need to be prepared to make capital expenditure when equipment that affects their service or production becomes or is about to become obsolete.

The control systems fitted to industrial gas turbines and their driven loads is no exception to this rule.

Owners and Operators of OEM supplied gas turbines are increasingly facing the need to upgrade their legacy control systems. It is not uncommon to see gas turbines from the 1970's & 80's still in operation with unsupportable legacy control systems.

Owners / Operators are now considering how to retrofit these control systems and have the option to use control systems provided by an organisation that is not the OEM.

Such non-OEM supplied system improvements can allow the operator to troubleshoot, tune, repair and make improvements independent of the turbine OEM using common hardware and software platforms that may be in use on many other parts of their plant.

The world has moved on from the supply of closed black box type gas turbine controls, with opportunities for Owners / Operators to exploit the availability of open technology and to extract running data and improve diagnostics and fault finding.

3. OEM or 3rd Party

Older OEM gas turbines often come with proprietary control systems that can be arcane to use and that make it difficult for Owners / Operators to troubleshoot, maintain or improve their systems without the direct involvement of the OEM. There are plenty of examples of older systems that use parts and equipment that cannot be sourced through normal procurement routes or that require OEM licences to run diagnostics software.

When originally developed, the OEM control system may have been developed because of the lack of commercially available technology that could be used or adapted. Many OEM control systems are highly bespoke and have been tailored to work with specific gas turbine type. The development of universal logic controllers that could be configured to suit a variety of engine types is a relatively recent phenomenon that has matched the growth and capability of industrial Programmable Logic Controllers (PLCs) and Process Automation Controllers (PACs)

There are reasons for the OEM to adopt such a bespoke approach to the control systems. This prevents end users from altering operating parameters, minimises the risk of modifications and ensures consistent machine deployment to allow OEM engineers to provide support assistance. Customers who retain the controls system provided by the OEM are often forced to rely solely upon the OEM for troubleshooting, service and parts which can be a laborious and expensive experience.

Older systems may suffer from either a lack of documentation or possibly worse, poor documentation. Programming and configuration can be difficult to understand - not only for Owner / Operator technicians, but for OEM field service personnel as well. Reports are given of cryptic alarm messages and no useful help feature with poorly documented diagnostic alarms.

Nevertheless, there are also clear reasons to use the OEM to provide updates, modifications and a controls retrofit. The OEM has the history, intimate

knowledge of the design of the machine, its operating characteristics, control algorithms and parameters. In some engines where emissions control technologies are employed the algorithms can be locked by the OEM. There can also be a culture of fear with operators fearful to use Non-OEM 3rd parties to provide services in case the OEM walks away from providing ongoing mechanical support for an engine.

A recent example saw a client who was clearly fed up of waiting for the OEM to repair his fuel valves but would not commit to use another company to work on the valves in case the repaired fuel valves damaged the engines. This was despite a full testing regime, quality controls and the like in place.

However, there are compelling reasons to use a Non-OEM third party organisation to provide the control system retrofit. Benefits of this approach include significantly reduced costs, reduced project timescales, faster maintenance response times, the use of commercially available hardware, better support and a resulting open system. The Owner / Operator is left with a system that in many ways is superior to that of an OEM supplied system and that makes use of modern equipment and technologies.

Owners / Operators who use OEMs can often face long delays as equipment is repaired or updated and can be at greater commercial risk while assets are unavailable as a result of machine downtime. Many operators seeking third party Non-OEM control systems have got disheartened with the response of OEMs to support their legacy control systems with the OEM will almost always saying that "your system is obsolete and must be upgraded."

Such operators recognise the importance of access to machine and diagnostic data, the ability to control their own destiny and take ownership of their gas turbine and its control system.

Using the right 3rd party organisation to provide such non-OEM retrofits is crucial. The design of a gas turbine governor controller is a non-trivial application and needs to be undertaken by an organisation with experience of deploying complex control and safety systems with an understanding of the processes involved in deploying retrofit control systems.

4. Why Retrofit?

Any retrofit of the gas turbine control system will involve the commitment of significant sums of money that will need to be justified to senior management.

Experience shows that most failures on gas turbine systems are due to the control systems, field instrumentation and the auxiliary systems. Whilst failures of the engine do happen they are more often a result of external sub systems and not the engine itself. There are many examples of maintained machines still running for over 40 years.

Industrial gas turbines are often redeployed and older control systems may not be suitable new applications. This can be an optimum time to retrofit the gas turbine control systems.

There are some key issues to consider when undertaking a control system retrofit on a gas turbine that can include:

Older / Existing control systems	Replacement control systems
Safety	
• May no longer comply with current machinery safety standards • May no longer able to safely control the turbine within the original design limits set by the OEM • Risks to personnel and assets • Reduced life of the turbine components	• Adoption of latest machinery safety standards • Decreased risks to personnel and assets • Life extension
Reliability	
• Unplanned turbine shutdowns and trips • Costly in terms of manpower and possible loss of capability • Deterioration of turbine resulting in failure • Long standing reliability problems with electro-mechanical components • Unacceptably high failure rates	• Fewer unplanned shutdowns • Better diagnostics • Improved reliability • Ability to implement higher availability architectures (1oo2) • Solid state equipment • Lower failure rates
Efficiency	
• Operate the gas turbine turbines below maximum efficiency • Use of larger safety margins • Slower load and transient response times	• Operate the turbine more efficiently • Reliable and precise control • Improved load and transient response • Improved automation of turbine and driven load

Older / Existing control systems	Replacement control systems
	• Improved monitoring, trending, event logs and SOE recording • Increased operating flexibility • Enhanced alarm and trip detail • Faster, more accurate access to operating performance and parameters
Obsolescence	
• Limited in their scope for expansion • Hard to come by with limited availability • Expensive	• Flexible hardware allows future expansion • Readily available hardware • Lower cost hardware • Common spares holding with other systems
Usability	
• Closed systems • Unexpandable • Inflexible • Lack of communications support	• Scalable • Expandable • Flexible • Support for sophisticated communications • Data acquisition • Remote access • Diagnostics

5. Retrofit Justification

Justifications need to be made to warrant the retrofit of any gas turbine control system and an obsolescence study can help with highlighting critical equipment and identifying what equipment has reached a critical state.

An obsolescence study may typically review factors such as:

- **Operational Reliability -** How reliable the equipment in use
- **Spares Availability -** How good is the spares holding or how easily spares can be obtained
- **Operational Longevity -** How long is the equipment required to operate
- **Vendor Support -** The capability and / or interest the OEM has in supporting the equipment
- **System Criticality -** A measure of how critical the successful operation of the equipment is in use

Such a review may categorise equipment with a High, Medium or Low risk assessment outcome using defined criteria. Equipment that has a High risk outcome would typically be a system whose failure to operate correctly or to be supportable presents an unacceptable risk to the Owner / Operator.

Owners / Operators may have other demands and requirements that are not critical for plant operation, but where new systems are required to accommodate system enhancements. Such demands can be difficult to quantify in terms of savings etc. but can be justified in terms of improved efficiencies, data / communications integration, spares holding, compliance with operating standards etc.

Once an obsolescence study and justification has been made, an evaluation process would normally be undertaken using a cost-benefit analysis to make a final decision whether to proceed.

6. What to retrofit

Gas turbine control system retrofits could potentially cover every instrument and control aspect of the machine.

This may include the control and safety hardware and software elements, user HMIs, control panels, fuel valves, valve actuators, vibration monitoring system together with other elements of the instrumentation and controls found on a gas turbine unit such as the fire detection and suppression systems, LV MCC et al.

In practice a more measured approach is often taken with the replacement of legacy mechanical / hydro-mechanical equipment with software, electronic or electrical control systems to provide a significant improvement in system reliability.

A typical scope of a gas turbine controls system retrofit might include:

- Replacement field instruments such as pressure switches, temperature switches, vibration sensors and speed sensors. Replace switches with transmitters for improved diagnostics.
- Replacement gas and liquid fuel control valves with modern intelligent valves
- Replacement governor controller
- Replacement sequencer logic
- Addition of HMI with event / alarm recording
- Replacement vibration monitoring system with additional sensors to improve machine diagnostics and evaluation unit

- Replacement machine safety system functions including overspeed trips, emergency shutdown, fuel shut-off etc.

Gas turbine control system retrofits may typically also consider the update of key auxiliary systems associated to the engine including:

- Generator control and protection
- Compressor control and anti-surge protection
- Fire detection systems
- Fire suppression systems
- Electrical load management
- LV Motor Control Centres (MCCs)
- Solenoids and actuators

Advances in technology provide significant advantages in reliability and supportability with easy integration into newer control and safety systems.

7. Control Platforms

The selection of suitable control platforms for turbine control is critical to a successful retrofit project.

Control platforms used as part of a control system retrofit are often selected from industrial grade Programmable Logic and Automation controllers. Typical controller families may include Rockwell ControlLogix and Siemens S7 platforms coupled with operator HMI facilities running on flat panels or desktop computers.

The use of standard equipment has a number of key benefits to Owners / Operators:

- Readily available hardware
- Modular technology
- User familiarity
- High quality developed systems
- Cost effective
- Worldwide support
- Open technology

Systems based on such equipment are readily supportable by Owners / Operators with hardware and software that is widely used throughout industry.

When deployed, these control platforms provide interchangeable hardware and portable software, greater standardisation, OEM and supplier independence together with upgradeable technology with global support from established companies.

Such systems provide a wealth of benefits including:

- Integrated governor, EGT and turbine sequencing
- Standard software library modules and programming tools
- Increased reliability over older electro–mechanical systems
- High level of built-in diagnostics
- Optional load control packages for electrical and turbo–compressor loads
- Extensive communications to HMI, DCS and SCADA systems

The control system allows close integration with other sub-systems within the gas turbine control system including vibration monitoring and safety systems. I/O for field devices such as flame detectors, LVDTs etc. is handled using specialist I/O modules.

Safety systems are designed to meet the latest machinery safety standards.

8. Fuel Systems

One of the key systems that is often upgraded during a control system retrofit is the gas or liquid fuel systems.

Older fuel valves may be hydro-mechanical or simple multi-stage valves that can have ongoing mechanical problems with poor dynamic response resulting in poor control of the gas turbine speed and load control.

Upgrades of the gas turbine fuel system will typically include the replacement of the fuel modulating valve with a modern digitally controlled valve that may have integrated diagnostics and fuel flow metering.

Many Owners / Operators also take the opportunity to replace the safety shut-off valves and instrumentation on the fuel system. In some instances it may be simpler and more cost effective to replace the entire fuel package with a pre-tested drop in replacement.

9. Fire detection and suppression

Gas turbines present a particular challenge with respect to fire with risks present in gas or liquid fuel, lubricating oil, rapid development of fires and the presence of high thermal loads. Risks are present in the turbine enclosure and within the auxiliary equipment enclosures.

Advanced fire detection systems can provide flame and heat detection within the turbine enclosures with detectors chosen to minimise false alarms and trips. Integrated fire detection and suppression

systems can provide compliance with the latest standards with respect to personnel and asset protection.

Gas turbine fire suppression systems have traditionally made use of CO2 or halon 1301 gasses to provide the suppression agent.

Newer suppression gasses provide quicker residue-free fire extinguishing and are typically applied as part of “total-flood” design that requires a tight enclosure around the gas turbine to build up the necessary gas concentration.

Older gas turbines may have mechanical issues including the deterioration of door seals, malfunctioning fire dampers and the removal of enclosure panels during past shutdowns and outages. All of these may affect the concentration levels of the suppression agent and may ultimately not supress a real fire incident.

Many Owners / Operators take the opportunity to update the fire detection and suppression systems as part of gas turbine control retrofit to provide an integrated system.

10. Load Control

The adoption of modern control systems for the gas turbine allows the Owner / Operator to integrate driven load control systems for mechanical and electrical systems.

Typical examples might include:

- Integration of compressor anti-surge control systems into the turbine control system to reduce system interfaces and provide a true unit control system.
- Integration of Generator Control Panel (GCP) functions to provide stand-alone generator package with extensive diagnostics and breaker control.
- Integration of Power Management Systems (PMS) to control electrical power generation and distribution systems.

11. Conclusions

There are clearly many reasons that Owners / Operators may consider a Gas Turbine Control System retrofit.

Some of major issues that should be considered should include:

- Safety
- Reliability
- Efficiency
- Obsolescence
- Usability

Demands to lower costs leave opportunities for Owners / Operators to consider the use of non-OEM companies to provide the retrofit control systems for their gas turbines.

The use of non-OEM organisations can provide Installed systems should be reviewed to determine what parts of the control and safety system, instrumentation, and auxiliary equipment should be part of the retrofit.

The scope of retrofit should be considered and the opportunity taken to upgrade fuel systems and ancillary systems such the F&G detection, F&G suppression and LV MCC as appropriate.

Modern control systems provide the ability to provide:

- Hardware independent system
- Improved safety integrity
- DCS / SCADA Interface
- Improved Turbine Control
- Exhaust temperature monitoring
- Standard I/O and signal interfaces
- Improved diagnostics and operator information:

When selecting an organisation to undertake the retrofit work care should be taken to use companies that have a credible track record and experience in providing gas turbine retrofit control systems with a background in providing control and safety systems.

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He is Managing Director of Proeon Systems and oversees the delivery of the company’s core objectives.

Proeon Systems are a specialist systems integrator with experience in the supply of control and safety system for high criticality applications including gas turbine control, F&G systems and process control.