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Application Note 83407
Original Instructions

Steam and Gas Turbine Control Retrofits

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Abstract

Power producers throughout the country are experiencing problems with technical, economic, and political issues. While no one solution can rid power generators of these concerns, control system retrofits can provide solutions for technical issues and contribute to resolution of economic and political issues.

This paper explores the opportunities for turbomachinery control system retrofits, why one might consider such a retrofit, and what benefits have occurred for those who chose turbine controls upgrades. Additionally, this paper explores an evaluation process for such capital expenditures and considers the issue of "must do" projects versus "want to do" projects.

Introduction

The power generation industry is experiencing crucial times, perhaps the most crucial in decades. Increases in peak demand continue to stress utilities in many parts of the country. Limited power reserves and little or no expansion plans add pressure to existing plants, in some cases it may cause the use of power generation equipment that is rarely operated and often inefficient. Today's power demands are often being met with equipment that is becoming less reliable due to repair difficulties, spare parts scarcities, and more frequent unscheduled outages.

Added to this is a business climate filled with complex and diverse threats including impending deregulation of the power industry and tightened emissions standards. The result of these challenges is interest in opportunities to improve performance, enhance reliability, and upgrade availability. The advent of digital, industrial control technology has brought increasing focus to improving control systems throughout the power plant.

An area of increasing consideration is the upgrade of turbomachinery controls. This paper reviews primary reasons for control retrofit consideration, presents a structured approach to retrofit evaluation, and reviews the benefits received from control system retrofits.

Why Retrofit?

Economic pressures dictate plant managers must evaluate and scrutinize purchase decisions more so than in years past. Control retrofits involve thousands of dollars and, therefore, must be justified. The dominate question then becomes, why retrofit? Key areas can be summarized as follows:

- Safety
- Availability
- Reliability
- Economic obsolescence
- Control system mortality
- Technical obsolescence
- Operating changes

A detailed look at each of these areas is a worthy consideration.

Safety

Many turbomachinery control systems in use today are no longer able to safely control the turbine within the original design constraints of the OEM. This may lead to reduced life of the turbine components, major turbine failure, and costly downtime. A few reasons may be:

- Retirement of key operating personnel familiar with operation of the older turbine.
- Retired or mothballed turbines being reactivated for service after long periods of time without maintenance or proper storage.
- Inability of older controls to maintain calibration, increasing the probability of failure due to recalibration errors.

As safety increasingly becomes an issue, the cost of insurance will likely increase as well. Therefore, turbine control retrofits can impact insurer confidence and result in cost effective insurance premiums.

Availability

Availability can be defined as the probability that a system will be operable for a given period of time. One economical method of increasing plant availability is the retrofit of original control schemes with more reliable digital control systems. Many factors affect availability, but several major items to consider are:

- Input/Output (I/O) - wiring, sensor age and availability.
- Lack of timely and cost effective OEM spare parts, engineering, and field support.
- Control design improvements available, i.e., analog vs. digital.
- Lack of present controls to provide accurate and helpful turbine diagnostic information before, during, and after trips.
- Remote operation.
- Redundancy of control hardware to prevent nuisance trips due to single point failures.

Reliability

We expect to operate the turbine as specified by the OEM without frequent operator intervention. Unplanned shutdowns are not only costly in terms of manpower and possible loss of revenue, but also with regard to the overall life of the turbine. Items to consider for improved reliability are:

- Improved state-of-the-art, supportable, digital control hardware and software.
- Improved control design philosophy.
- Reduction of high maintenance control hardware items with high failure rates.
- Increased maintainability, optimizing manpower and maintenance planning.
- Consolidation of control systems support, i.e., same controls operate many different types of gas or steam turbines.

Economic Obsolescence

For safety reasons, older control systems operate turbines below the point of maximum efficiency. The vintage mechanical/hydraulic and electronic controls require larger safety margins because of setpoint drift, ambient effects, as well as slower load and transient response times. Modern digital controls are able to play an ever-increasing role in improving turbine efficiency as they reliably and accurately operate the turbine closer to optimum running conditions. Items to consider are:

- Reliable and accurate control.
- Automation and improvement of load and transient response.
- Ease of calibration or self-calibration.
- Increased monitoring and trending capabilities.
- Increased operating flexibility.

Control System Mortality[1]

To understand the useful life of control systems in power plants, a typical mortality curve (Figure 1) may prove helpful. The curve shows that control system failures will increase as the control ages and its useful life is reached. From that point the cost of maintenance and troubleshooting will increase until some point at which the cost to upgrade will more than offset the continuation of high maintenance costs, or unexpected downtime. Current estimates indicate control system useful life expectancy is approximately 15–20 years after initial first year burn-in. Many power plants currently have control systems beyond or approaching this expected life period and would be candidates for cost reducing upgrades.

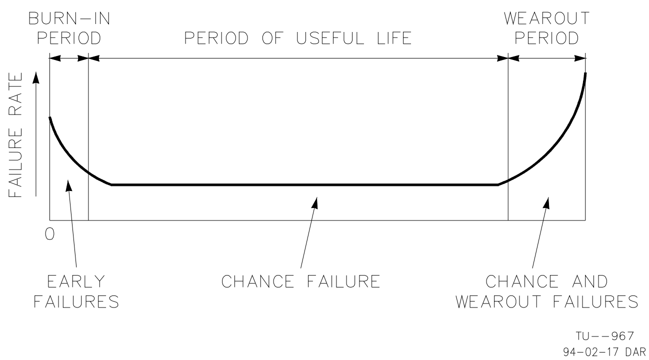

Figure 1. Mortality Curve

[1]—Elliott, Thomas C., Upgrading Power Plant Controls, *Power*, September 1987

Technical Obsolescence

Do you need additional capability such as data acquisition or improved man/machine interface? Older mechanical/hydraulic and analog electronic controls do not lend themselves to system changes without the addition of expensive hardware. On the other hand, digital controls are inherently well suited to provide these benefits, and future enhancements.

Effective data acquisition and increased man/machine interface allows operations to be more responsive to transient conditions. Operators are also better able to assist engineering and management in assessing turbine conditions and planning cost effective maintenance schedules. Items to be considered are:

- Enhanced alarm and trip detail.
- Faster, more accurate access to operating details.
- Hard copy of logs and sequence of events.
- On and off-line trending and operating parameter graphic displays.

Operating Changes

To meet changing needs, turbines are sometimes used in ways other than those originally intended. Many turbines once used only for base load, are now used for cyclic or peaking duty. In some cases, multiple fuel capability is added to older, single fuel gas turbines. Used turbines are purchased and adapted to new functions. Any one of these situations may require upgrading or retrofitting of the control system. Additional items for consideration are:

- Turbine relocation.
- Turbine hardware retrofit.
- Change of operation from original OEM intent.
- EPA emission requirements.

Retrofit Justification

In contemplating turbine control retrofits, it is appropriate to consider the justifications that can be made. Specifically, consideration should be given to whether a retrofit is a "must" or a "want".[2]

[2]—Ibid.

A "must" is a condition in which existing controls have reached a state of real concern, and could be threatening the operation of the plant. For example, the current control system has exhibited deterioration and is ultimately going to fail, possibly causing the plant to experience inoperable conditions. Because of the critical nature, this situation typically represents a management decision and may not require a justification study. Time may be of the essence.

A "want" is a condition that may not be critical at this time for plant operation, but a new platform is needed for future instrumentation and information system demands. For example, plant operations may have plans to integrate turbine data into the plant control system for operational reviews and analysis. With older mechanical/hydraulic or analog controls this is not possible. However, current digital systems exist that readily interface to a wide array of plant communication networks. This type retrofit represents plant improvement, ultimately evaluated on its contribution to efficiency improvements. A study would usually be required before approval. Such a project can be difficult to calculate a return on investment (ROI) analysis, however when viewed in terms of the contributed benefits to overall plant improvement it becomes easier. The contribution of these benefits will depend on several factors, including:

- Comparative quality of turbine operations with existing controls and its contribution to plant operations.
- Plant operating philosophy.
- Local economic conditions and future projections.
- Projected changes in control scheme with proposed instrumentation.
- Available manpower and alternative manpower uses due to new control efficiencies.

Retrofit Evaluation

Having considered justification for control system retrofits, it is appropriate to consider an evaluation process. Generally speaking, projects of this nature should be approached from a cost-benefit analysis. If the retrofit project stills looks promising after such analysis, it would be appropriate for management to consider as part of their capital planning process. For such projects, a cost-benefit analysis should account for several items, including:[3]

[3]—Ibid.

- Capital investment—direct and indirect costs, insurance, taxes, etc.
- Replacement costs—expenses associated with energy replacement if retrofit cannot be completed during scheduled outage and plant is not available for operation.
- Availability costs—expenses associated with existing controls causing unit to be unavailable for operation.
- Efficiency savings—savings associated with any energy (heat rate) improvements due to controls upgrade.
- Manpower savings—savings due to reduced manpower operational needs or reduced maintenance. Also savings resulting from re-deployment of existing manpower.

Accumulating costs such as these may prove to be difficult. However their determination will contribute to a better evaluation and justification analysis.

To assist in the decision process it may prove helpful if a structure is applied. Figure 2[4] represents a sample flow chart for reviewing existing and proposed systems, as well as estimating associated costs for consideration.

[4]—Ibid.

Retrofit Benefits

Control system retrofits yield benefits of varying nature and degree. Experiences indicate derived benefits fall into two general categories:

- monitoring and control
- economic

While the following represents benefits from recent retrofit projects it is by no means as exhaustive list of possibilities.

Monitoring/Control

Today operating plants have control systems that range from pneumatics dating back to the 1950s, analog electronics from the 1960s and 70s, to modern digital based systems with sophisticated communications and networking schemes. Depending on the vintage of the original control, the retrofit system can offer many benefits in the monitoring and control areas. The primary benefits appear in four areas:

Performance

Monitoring and control instrumentation can make it easier to predict the efficiency of the turbine between overhauls. In some cases the ability to log and trend data over time allows the engineering staff to conduct efficiency analysis to determine not only current performance, but also investigate where possible losses may be occurring that could be corrected during the next turnaround.

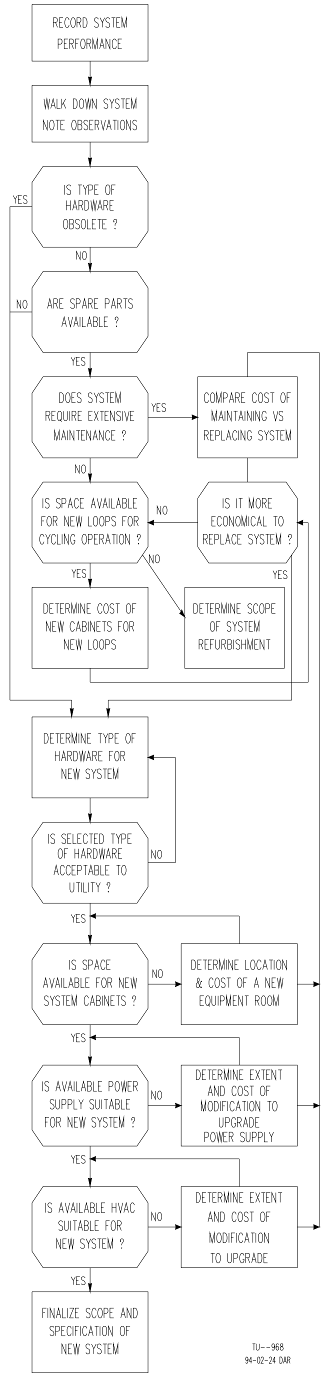

Figure 2. Decision Flow Chart

Accuracy

Through enhanced monitoring and control accuracy some customers have been able to increase efficiency and power output. Recently a customer indicated they were able to operate on temperature control (gas turbine), and producing more megawatts than previously possible. They can push the turbine a little harder, because they know where the turbine is operating and more accurately predict safety margins. More accurate control also contributes to reduced wear on parts that undergo thermal stress.

Automatic Start-up
One advantage of application software flexibility is programming the start sequence and incorporate parameters to insure controlled starts with less thermal stress to the turbine. Less stressful starts result in extended turbine life.[5] New auto-startup features allow digital controls to interface with electro/hydraulic devices through push-button operation from turning gear, through warm-up, auto-synchronization, and initial generator loading. Steam turbine applications can incorporate rotor stress calculations and automatically choose the proper acceleration rate, speed holds, and generator loading rates. As with temperature control on gas turbines, this minimizes stress on the steam turbine and extends predicted rotor life.

[5]—Tena Britt and Alan Metzger, Digital Control Retrofit of an Industrial Gas Turbine, International Gas Turbine and Aeroengine Conference, Cologne, Germany, 1992

Flexibility
Modern digital control systems inherently contain flexibility in both hardware and software. Hardware feature flexibility in that many options exist for I/O configuration, communications interface, and configurable control loop rates, to name a few. This allows the engineer to custom tailor controls to plant specific requirements. And if operational requirements change over time, the control system can be modified to match new operating parameters.

In a similar vein, software can be custom programmed to precisely control turbine operation in a manner appropriate for the plant. Again, if operations change and control algorithms need to reflect a change, software can be modified to enhance turbine operation under the new control parameters. Software modifications are relatively simple with modern digital controls, most of which can be performed by plant personnel with moderate training. Many software changes are achieved through adjustments (tunable), rather than extensive software programming.

Availability of Starts
When the dispatcher calls for peaking units to come on line, it can be frustrating to have turbine controls prevent immediate dispatch of a unit. A new control system can put a unit back into ready condition, eliminating the problems associated with older control systems. Recently a customer indicated they would sometimes take more than a half hour to start a peaking gas turbine. Now that unit is available immediately due to the improvements in the control system. A side benefit of this retrofit was reduced manpower needs during startup. The operating personnel could be dispatched to other assignments, contributing to better overall plant operations.

Economic

A control system retrofit must result in some economic benefit in order for management to justify the capital expenditure. In the case of turbine retrofits the economic benefit generally comes in the form of cost savings, rather than revenue generation. However, increased power production through efficiency gains can result in revenue enhancements. There are three primary areas that hold significant opportunities for savings:
- operating costs
- cost of spares
- maintenance costs

Operating costs will be reduced by improved performance of the turbine, increased power production, reduced downtime, or perhaps other operations related savings. Reduced manpower during starts will result in cost savings, particularly with peaking units.

The cost of spares may result in savings as new hardware would be readily available and competitively priced. The need to purchase “rare” components can be significantly reduced, if not eliminated altogether.

Maintenance savings can be obtained from reduced manpower requirements to troubleshoot the old controls, freeing personnel to maintain other plant hardware. Additionally, maintenance costs may be reduced with a new control because less service cost would be associated with the new control, and initially the new hardware would be under warranty.

Additional economic savings are attainable, some common to most plants, others unique to a particular plant. The point being, control system retrofits due indeed generate savings which will offset to varying degree the initial capital investment. How fast the investment is recouped will be plant dependent.

Conclusions

The introduction stated the power generation industry is experiencing crucial times. Power generators face many challenges from several fronts. This requires utilities and other power producers to look for new ways to enhance their position. Turbomachinery control retrofits offer one part of a solution to these challenges.

There are many reasons to consider turbomachinery control retrofits. Generally speaking these can be grouped into six categories:

- safety
- availability
- reliability
- economic obsolescence
- technical obsolescence
- operational changes

Before launching into a control retrofit it is appropriate to investigate the nature of the project. Is this a “must” do in order to insure the operational integrity of the turbine and possibly the plant, or is it a “want” to do project that will enhance plant operations. Ultimately “must” projects tend to get approved without detailed management analysis, while “want” projects need to go through cost-benefit analysis before approval.

In the end, turbomachinery control retrofits can result in many benefits. Customers have experienced improved monitoring and control, economic savings, enhanced reliability and serviceability, and improved performance. Digital technology offers enhanced turbine control solutions not achievable in older control technologies. Power producers looking for new opportunities to position themselves against current challenges should consider turbomachinery control retrofits.

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