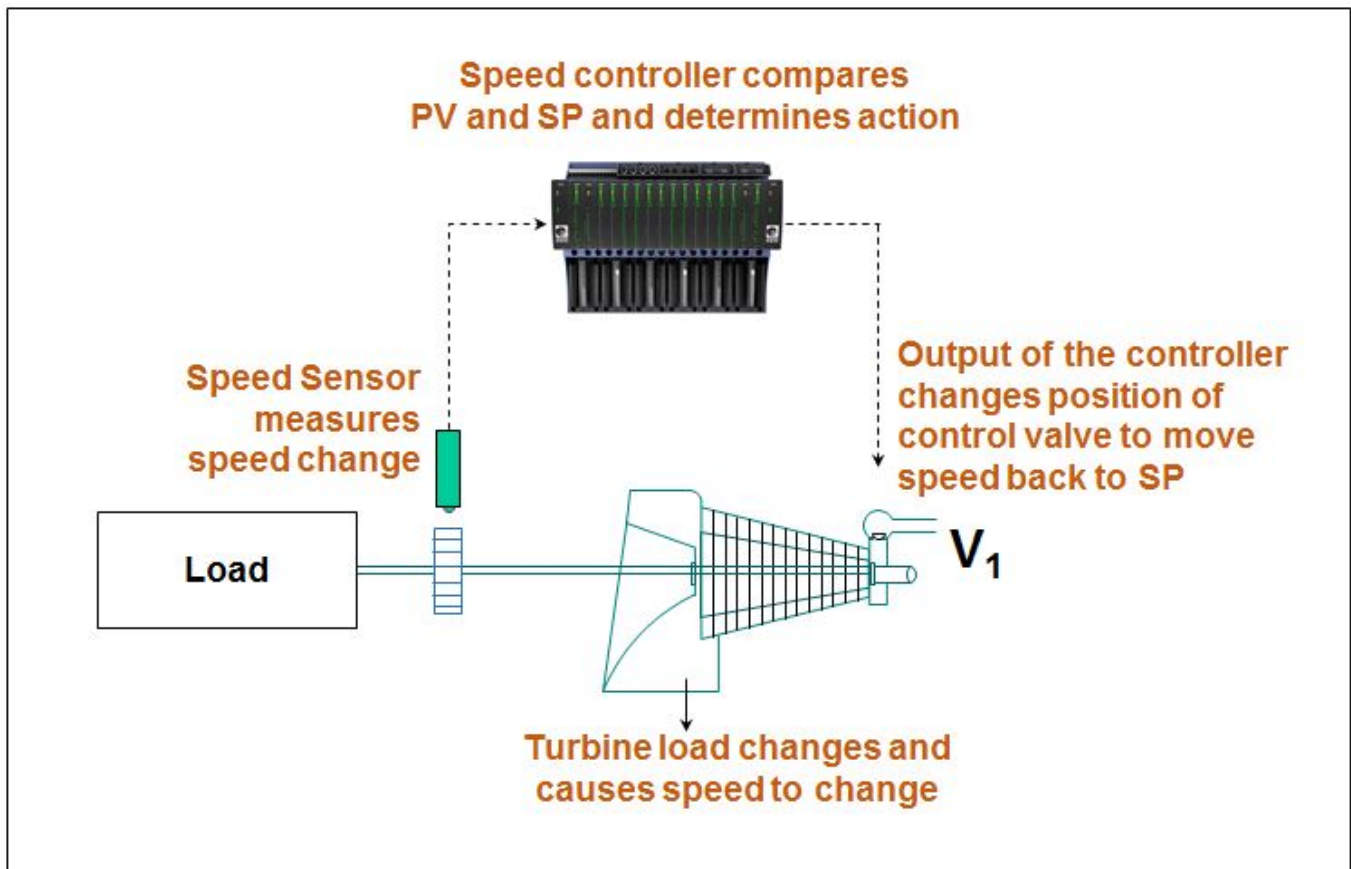




**Expertise in Turbomachinery Controls**

WHITEPAPER

# Improve Operations with a Steam Turbine Mechanical Retrofit



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This article explains how to improve facility operations with a steam turbine mechanical retrofit.

The main reasons for deciding to retrofit a steam turbine with modern day equipment and controls is to improve safety, reliability, availability and controllability. When it comes to safety, older steam turbines are often operated with some degree of mechanical wear to the OEM governor and mechanical overspeed device or may have had modifications that are unsafe. In addition, older steam turbine hydraulic control systems can often have oil leakage which can be a fire hazard. Retrofitting the turbine controls can also allow the system to meet current API standards; API 611 Standard, Steam Turbines - General Purpose, API 612 Standard, Steam Turbines – Special Purpose Applications and API 670 Standard, Machinery Protection Systems.

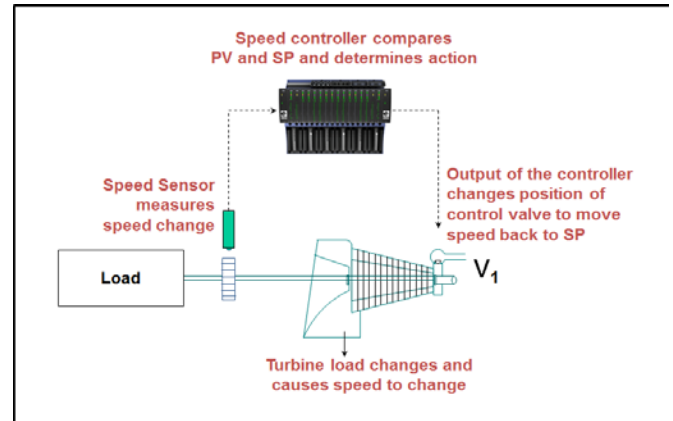
A retrofit also improves the reliability and availability of the unit by preventing frequent nuisance trips and reducing maintenance time associated with old and unreliable equipment. Maintaining older equipment can be expensive and spare service parts are not always readily available. It can also resolve issues with oil contamination.

There are a variety of control issues that can be resolved by retrofitting the steam turbine. One such issue is the inability to maintain speed which results in unstable process control. Often times the turbine is controlled or started manually which can lead to inefficiencies and inability to recover from process upsets. For example, a fly-ball governor can have speed swings between 50 to 200rpm. Some older systems have no means of automatic control outside minimum and maximum governor speeds. Not having automatic startup capabilities leads to inconsistent startups, longer loading times, thermal stress on turbine components and unit trips. Having electronic overspeed prevention control can greatly reduce the number of overspeed trips. Overspeed trips as well as trips due to improper manual startups, all lead to mechanical stress on the unit.

With today's modern control systems, it is possible and desirable to integrate speed, performance and antisurge control loops. Doing so can increase the operating envelop of the unit which leads to more

efficient operation as well as quicker recovery from process upsets.

When you look at a typical control loop, there are four basic elements; the process, measurement, control and the control element.



**Figure 1. Basic elements of a Control Loop**

When you have a change in the process, you have a change in the process control variable. In order to act on this change, you need to accurately measure it. The controller then compares the process variable with the desired set point and takes action by sending a signal to the control element. Then the control element responds accordingly in order to return the control variable back to desired set point. In order to optimize the control loop, all four blocks need to be optimized. A steam turbine mechanical retrofit involves the turbine shaft speed measurement (speed sensor), the control (high speed digital controller) and the control element (the actuator for the steam turbine governor valve).

## Speed Sensors

Speed sensors are non-contact sensors that convert mechanical motion into a proportional frequency output. There are two main types of speed sensors that are used to measure speed. These are 2-wire passive sensor (variable reluctance sensor) and a 3-wire active sensor (Hall Effect sensor or proximity probe).

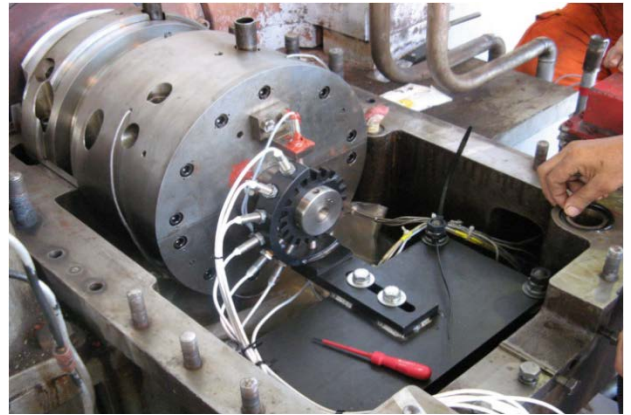
A passive speed sensor consists of a coil of wire wrapped around a magnet. As gear teeth (or other target features) pass by the face of the magnet, they

cause the amount of magnetic flux passing through the magnet and consequently the coil to vary. The moving target results in a time-varying flux that induces a proportional voltage in the coil (pulses). The resulting output is an approximate sinusoidal waveform. Passive sensors are self-powered and can be used at distances up to 1000 meters. These are generally less expensive than active probes. However, passive sensors are sensitive to improper speed gear tooth designs and can double the pulses on sharp corner gear teeth. These sensor types cannot typically measure below 100 – 200 rpm and requires a small air gap setting between the sensor and the speed gear. An active speed sensor detects target-induced flux changes from where its transducer element is situated, between the magnet and the target. Unlike a passive sensor, an active sensor is sensitive to the magnitude of flux, not its rate of change. The resulting output is a square waveform. Active probes can be used to measure speed at near zero rpm and therefore make them a good choice for uses on barring or turning gear logic applications. These probes are also more forgiving for all types of gear teeth shapes. However, these probes are not self-powered and require a 24 VDC power supply source. The cable length is limited to 250 to 300 meters. For hazardous area classifications, speed sensors are available in flame proof (explosion proof), intrinsic safe, or energy limiting methods of protection. The below picture shows a typical installation of a speed gear, speed sensor holder and speed sensors mounted directly to the turbine rotor. Typically, three speed sensors are installed for measuring the speed and three more are installed for the electronic overspeed protection system. One hot spare should also be installed for quick change out without disturbing the installation.

### Control Valve Actuators

Reliable steam inlet control valve (governor valve) actuation is required for precise electronic speed control of the steam turbine. Actuator selection involves determining the proper actuation device which can be pneumatic, hydraulic, I/H and way valves, electric or electro-hydraulic. Stroking speed of the actuator is an important factor and should be matched to the speed of response required by the

driven equipment. Actuator sizing involves determining the actuator net thrust and stroke distance requirements.



**Figure 2. Speed Gear and Speed Sensor Installation**

Pneumatic actuators are a simple and cost effective method of modulating the steam inlet control valve. These actuators are low cost, low maintenance, simple to mount, provide field reversible spring action and are an ideal selection for most single valve governor valve retrofits. They are also used for most mechanical retrofits requiring actuation of pilot fed power cylinders utilizing existing mechanical feedback. Typically, these actuators have the required work force and speed for most applications except generator control.



**Figure 3. Pneumatic Actuator on pilot operator power cylinder**

Hydraulic actuators are very precise with a high workforce and have electronic (LVDT) feedback. These actuators can be used to completely replace the OEM

power cylinder actuator. They are more expensive than pneumatic actuators and use the existing control oil which needs to be free from contaminants. Hydraulic actuators are also available with a dual coil option which provides redundancy to the actuator electronic components.

Hydraulic I/H converters and Way-Valves are used in applications when a good working OEM equipment is retained to minimize the impact on the existing system and reduce the overall cost of the retrofit. I/H converters are used with existing pilot valve operated servo actuators and are available in simplex or redundant configurations. Way-Valves are designed to position an existing hydraulic power cylinder and are available in 3-way for single acting cylinders and 4-way for double acting cylinders. In addition to the way valve, a 4-20 mA position transducer must be mounted to the hydraulic power cylinder stem (or rotary valve shaft) to feedback the cylinder/valve position to the way valve. Clean control supply is a must for these devices and a duplex oil filter system is supplied to filter the oil to at least 10 microns.

Self-contained electro-hydraulic actuators are also very precise and high speed and can be mounted directly to the steam valve rack. Although more expensive, they do not require an external oil supply which in some cases makes these actuators a better choice when existing control oil contamination is of a concern. These actuators are also available with redundant control electronics and redundant power modules.

Electric actuators are very fast and accurate as well. They do require in many cases high voltage in order to operate large work forces. Electric actuators do not offer fail safe spring options, but can be supplied with a brake system for fail-in-place upon loss of electrical power or loss of command signal.

## Speed Control System

High speed digital controllers greatly improve machine control, availability and efficiency. These controllers can be programmed with advanced speed and extraction

control algorithms and allow coordination with the compressor capacity and antisurge control.



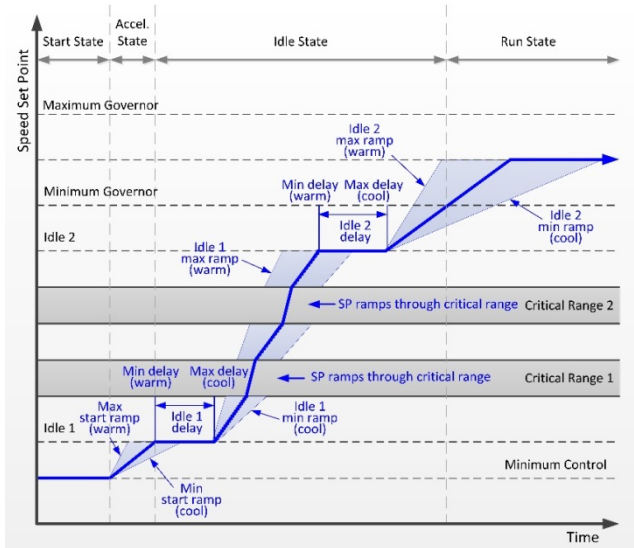
**Figure 4. Electric Actuator direct on valve rack**

They also provide the capability for automatic start and stop sequencing for hot, warm and cold starts which reduce thermal stress on turbine components. Using automatic start sequencing also reduces the risks of trips and can bring a compressor online quicker than manual starts by operators. The start and stop sequencing includes critical speed avoidance algorithms that can adjust to fluctuating steam conditions. Below is a typical automatic start sequence. In this example, the speed controller ramps the turbine to Idle 1 for a set hold time, it then moves quickly through multiple critical zones using faster ramp rates. After the Idle 2 hold time has elapsed, the turbine is then ramped to the rated speed set point.

In addition to providing automatic start sequences, the speed controller should have a means to provide overspeed avoidance. Rapid drops on the turbine load results in rapid acceleration which can reach the overspeed trip set point. When turbine speed increases due to the drop in load, the speed controller begins to close the inlet steam valve using normal PID control. Speed continues to rapidly increase and when it reaches the overspeed avoidance set point, the speed controller uses an open loop response to rapidly and incrementally step close the inlet steam control valve to drop speed below maximum governor



speed. The controllers PID control then brings the speed back to set point.



**Figure 5. Automatic Start Sequence**

## Mechanical Retrofit Process

At Compressor Controls Corporation, the first step in the mechanical retrofit process is to gather OEM turbine information to provide retrofit options and cost estimates as well as the necessary data for design. Some of the data needed includes:

- Make/Model/Frame size of turbine
- P&ID of the OEM turbine control system
- OEM control oil and trip oil schematics
- Governor valve actuator control linkage diagrams
- Turbine photos of OEM governor valve and OEM governor drive
- OEM mechanical cross sectional drawings of governor valve and governor drive assemblies
- Control oil supply pressure
- Secondary (regulating) oil pressure

We then conduct a site survey and inspect the existing speed governing and actuation systems. During this visit, the dimensional information for a new speed measurement kit and actuation kit are taken. Any outstanding information is collected and the mechanical retrofit options are discussed along with a “walk” through of the intended go-forward design

path. These activities are typically performed in less than a day per steam turbine.

After the information is collected and the design is agreed upon, the next step is to do the mechanical engineering design. This includes the design, fabrication, and procurement of the speed measurement and steam valve actuation kit components. Mechanical installation drawings as well as the engineering design and configuration of the speed control system are completed. Prior to the turnaround, all parts are shipped to the site in order to avoid unnecessary delays. On average it takes two to three days per turbine to install and complete the mechanical retrofit installation at site.



**Figure 6. Site Installation**