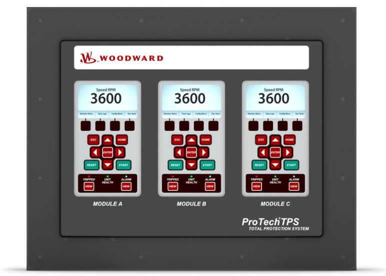
AEGIS

Loss Control

Steam Turbine Overspeed Protection Systems

White Paper



A Woodward turbine safety system

Overspeed Protection Evolution

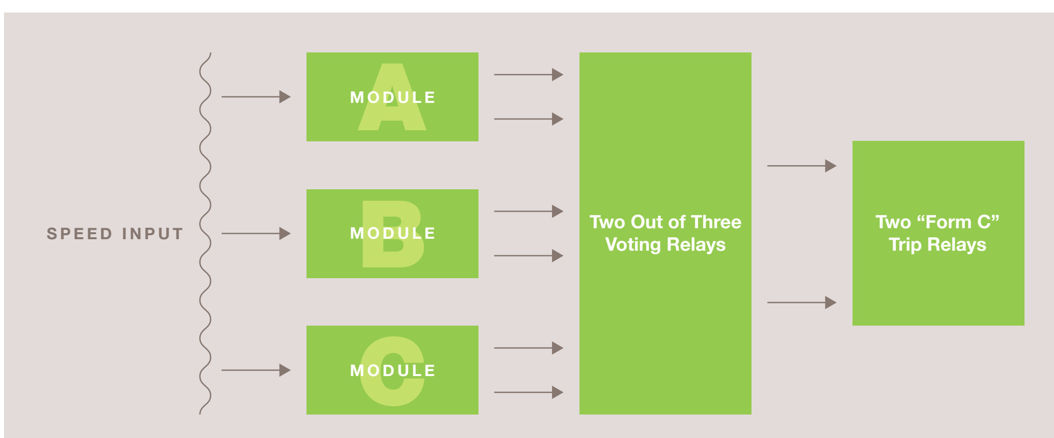
A steam turbine centrifugal explosion is our worst-case maximum foreseeable power plant machinery loss event. AEGIS along with the industry has learned to be cautious regarding these infrequent occurrences because of the destructive force they can unleash. A large steam turbine uncontained overspeed event can produce forces approaching those of a large plane crash. A single last-stage turbine blade can exert more than 300,000 pounds of force at synchronous speed.

Fortunately, these events do not occur frequently, and are highly preventable with routine inspection, maintenance and testing. The power industry as a whole has made significant gains in reducing overspeed events. From the early fly ball governors, to spring loaded mechanical bolts, to today’s modern electronic overspeed protection systems, governing systems have improved greatly. Operating procedures and systems have also evolved to better control turbine unloading. Additionally, gains made with control elements have improved valve closure reliability to stop steam flow to turbines.

As steam turbine operating temperatures increased, material upgrades have been attempted in an effort to limit excessive stem oxidation (blue blush), a condition that causes valves to stick. Valve actuating systems have evolved from mechanical to electronic hydraulic control systems that can be integrated with distributive control systems and electronic overspeed protection systems.

Electronic Overspeed Protection

The development of triple modular, electronic overspeed protection systems is the latest advancement in efforts to prevent overspeed events.



An overspeed protection system is the complete electro-mechanical system (mechanical hydraulic or electro-hydraulic) that senses the onset of an overspeed condition and automatically shuts down the turbine generator by closing (or opening) valves, solenoids and other devices necessary to bring the unit to a safe condition.

An overspeed detection system (ODS) is one part of the larger overspeed protection system. The function of the ODS is to sense the onset of an overspeed and provide a signal that can trigger the rest of the overspeed protection system, which then removes energy from the machine and brings it to a safe condition. The ODS supplies this signal by activating one or more electronic relays. Detection systems can use either magnetic pickups or proximity probes to monitor the shaft speed.

Proximity probes for ODS applications have constant amplitude at any machine speed, enhanced instrumentation health indicators, and a wider gap allowance (50 mil is typical). Their disadvantages include a lower temperature range than magnetic pickups and minimum spacing requirements between each probe.

Magnetic pickups, which are widely available, have higher temperature ranges than proximity probes. Their disadvantages include no signal at low speeds, tighter gap requirements, variable amplitude with speed, lack of instrumentation health indicators and electrical gap function.

Maintenance, Operations, Testing

As important as these advances in technology are, they must be accompanied by a thorough understanding of these complex systems as reflected in maintenance and operations.

An overreliance on these often-misunderstood modern electronic overspeed protection systems has led to several uncontained steam turbine overspeed events. The common use of the term “fail-safe” to refer to these systems has likely contributed to this costly misconception.

One clear advantage of electronic overspeed protection systems is that they can functionally test the complete system as a whole without subjecting the steam turbine and generator to the forces of a full trip speed. This is typically accomplished by lowering the trip point or injecting a signal. Many generating station operators have taken to conducting sectionalized overspeed trip system testing while the unit is offline. Although that can be helpful, our viewpoint is that a sectionalized test shouldn’t be considered a replacement for a full functional test of the overspeed protection system.

Despite the signaling device, the final control elements actuated on a trip signal are the stop valves, so they must be maintained in a high state of readiness at all times. We support the OEM recommendations for proscriptive cycling or timed full-stroke tests of stop and intercept valves to ensure they have not bound. We recommend valve cycling at least weekly.
Faulty extraction non-return valves (NRVs) can also allow steam to enter a turbine during shutdown, and we generally recommend cycling NRVs at least weekly.

Until the mid-1980s, large steam turbines were routinely taken off-line by reducing load to around 10 percent and then tripping, initiating valve closure and breaker opening. This could lead to steam turbine overspeed events. Operational changes were made to include the wide application of sequential tripping, ensuring that steam sources were isolated before unloading a generator.

AEGIS Loss Control's Experience

The improvements in overspeed protection systems, tripping procedures and operator training reduces the potential for catastrophic overspeed events. However, operational and maintenance complacency must not accompany new technology gains or the overspeed risk is not successfully averted.

There have been numerous steam turbine uncontained overspeed events in recent years involving turbines equipped with modern electronic overspeed protection systems. The common factors in these events were a lack of system maintenance and a failure to follow procedures.

Based on our experience with these matters, we have reevaluated our perspective on overspeed protection systems. Our concern is not limited to just the trip device but rather to the potential of overspeed events based on the entirety of the overspeed risk presented.

Mechanical vs. Electronic Overspeed Trip Protection

Concerns with the mechanical integrity of steam turbines and generators have led the industry to question the implications of rotor stresses imposed at full trip speed. Diminished mechanical integrity can result from age, wear, existing damage, operational issues, or less than optimal design configuration.

A 2013 Electric Power Research Institute paper titled "Steam Turbine Electronic Overspeed Protection System" advocates trip system conversion to an electronic overspeed protection system, in part for the advantages of lower-speed functional testing. We endorse robust electronic overspeed protection systems where testing can be performed without imposing potentially destructive rotor forces.

When thinking about converting to an electronic overspeed protection system, consider the following:

- Converting a steam turbine with an EHC system to an electrical overspeed system can cost up to $400,000.
- Converting a steam turbine with an MHC system to an electrical overspeed system can cost up to $1,000,000.

Elements of a Robust Overspeed Protection Strategy

Overspeed protection readiness and machine health can be assured by addressing the following key elements:

- Rotating element mechanical integrity verification (see considerations below).
- Annual functional trip testing of the system as a whole (documented). With electronic systems, this should be performed at or below synchronous speed.
- Trip testing for initial validation after front standard opening, after any significant thrust event, or after any ODS maintenance.
- Weekly simulated trip tests.
- Weekly steam valve cycling and overhauls at least every five years.
- Daily cycling of extraction non-return valves and overhauls at least every five years.
- Healthy hydraulic fluid demonstrated with routine hydraulic fluid sampling and analysis (at least quarterly with no varnish or water).
- Sequential tripping logic installed/procedure.
- Overspeed trip testing procedure (documented).
- Overspeed protection system training with supporting personnel qualification records.
- Electronic overspeed systems: triple modular redundant architecture, two-out-of-three voting logic to ensure that no single point failure will affect system reliability or availability, and redundant power supplies and processors.

Considerations & Recommendations

- Before performing a functional overspeed trip test, ensure the rotor has attained thermal and mechanical stability.
- Before overspeeding the rotor train at greater than synchronous speed, make sure the rotors have had a recent non-destructive examination (NDE) with a verification of rotating element integrity. As an example, GE G2 and G3 steam turbines must be compliant with TIL 1121, TIL 1277 or TIL 1886.
- Steam turbines that have shrunk-on discs, Grade C metallurgy, or are more than 50 years old should be considered overspeed testing risks. Grade C rotors were manufactured of chromium-molybdenum-vanadium (C-Grade CrMoV) from approximately 1949 to 1954 and are susceptible to creep rupture and low-cycle thermal fatigue in high-temperature regions.
- Elevated risks exist if anything is installed other than magnetic or 18Mn18Cr generator retaining rings, unless there is a known history of successful NDE without indications.
- A sequential tripping scheme should be verified in place. Reference: GE TIL 964, 886, GEK 110600 "Sequential tripping and limitation of motoring, and Westinghouse Operations and Maintenance Memo 092."

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