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Electronic Level Gauges Ensure Safe And Reliable Steam Generation

Robin Hudson explains how electronic level gauge technology ensures reliable and safe steam supply for power plants.

Power generation plants rely on the efficient, reliable and safe operation of boilers. Heat transfer efficiency is an important aspect of boiler operation, but the boiler must also generate high-quality steam that can be effectively utilised. Modern water tube boilers are designed to transfer the maximum amount of heat from combustion into water and provide clean, dry, superheated steam that drives the turbine. On top of the boiler sits a vessel known as a steam drum, which acts as a phase-separator for the steam/water mixture. The saturated steam is drawn out from the top of the drum and run through a superheater to produce superheated steam, which drives the turbine. Saturated water at the bottom of the steam drum is recirculated back into the water tubes.

The steam drum contains a turbulent mixture of water with many entrained steam bubbles, and steam above. Maintaining a constant liquid water level in the steam drum requires a complex control system to account for pressure changes in the steam drum that accompany changes in steam demand. The demand for steam varies inversely with pressure changes inside the steam drum, causing two phenomena called `shrink' and `swell', which make controlling steam level difficult.

As steam demand decreases, the drum pressure increases. The increased pressure compresses the entrained steam bubbles, and the drum level appears to shrink, even though the drum level is actually increasing. Conversely, as steam demand increases, drum pressure decreases and the bubbles expand, causing the drum level to appear to swell. To account for shrink and swell, a control system with three or more measurement points is used. A three-element control system monitors steam flow (derived from a pressure measurement), as well as feedwater rate and water level (both monitored directly) in the steam drum.

It is essential to accurately and reliably monitor the steam/water level in the steam drum. If the level is too low, the drum and tubes can overheat and sustain damage, and there is also a danger that the boiler could explode. If the level is too high, there is a risk that water will be carried into the turbine, causing enormous damage to turbine blades, cylinders and housing. Repairing such damage to a power plant can take months, if not years, to complete and can cause plant downtime costing millions in lost production and income.

There is a wide range of safety and monitoring equipment that can be fitted to boilers and are designed to help protect the boiler from operating outside the set parameters and shut it down to prevent a dangerous situation. This may include equipment such as alarms, water-level controls, burner controls and pressure-relief valves. For example, with the water-level controls, the first low-water-level alarm prevents the boiler operating when the water level is low, but allows the boiler to restart and resume operation once the water has risen to an appropriate level. The second low-water-level alarm is triggered at a lower level than the first, and this shuts down the boiler completely and requires a manual restart.

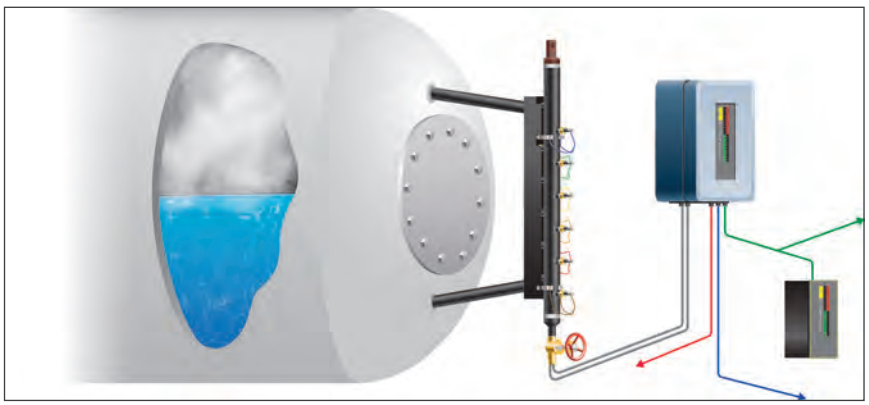
There are a dozen or more level technologies that could be considered for this application. Drum level is normally indicated both locally to the drum and remotely in the control room where the plant engineers will carry out an emergency shutdown should the conditions require it. Extremely accurate monitoring of these points needs to take place to avoid false alarms that could force a plant to shut down with a potential significant loss of revenue.

All national legislatures require monitoring and indication of feed water levels in steam generation plants. The ASME Boiler & Pressure Vessel Code (BPVC) is an American Society of Mechanical Engineers (ASME) standard that regulates the design and construction of boilers and pressure vessels. The standard is widely adopted, with over 100 countries accepting the ASME BPVC to meet government safety regulations. The ASME BPVC section I paragraph PG-60 lists most of the requirements for water level measurement instruments. The primary focus of these requirements is safe boiler operation.

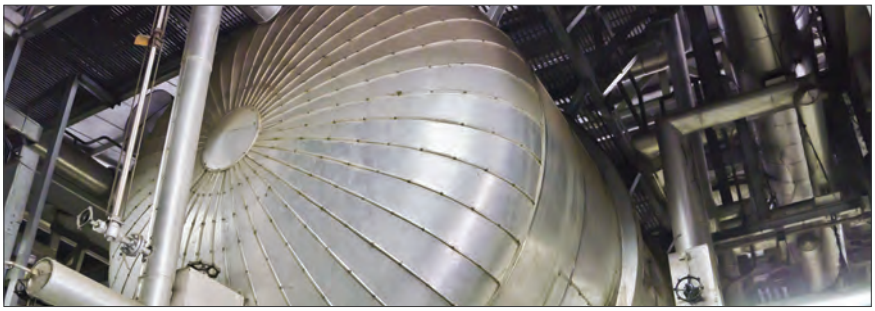
1. (PG60.1) All boilers having a fixed water level (steam and water interface) shall have at least one gage glass (a transparent device that permits visual determination of the water level).

2. (PG-60.1.1) Boilers having a maximum allowable working pressure exceeding 400 psi (3 MPa) shall have two gage glasses. Instead of one of the two required gage glasses, two independent remote water level indicators (two discrete systems that continuously measure, transmit and display water level) may be provided.

3. (PG-60.1.1) When the water level in at least one gage glass is not readily visible to the operator in the area where control actions are initiated, either a fibre optic cable (with no electrical modification of the optical signal) or mirrors shall be provided to transfer the optical image of the water level to the control area. Alternatively, any combination of two of the following shall be provided: a. An independent remote water level indicator; b. An independent



Hydrastep system.



Industrial boiler

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continuous transmission and display of an image of the water level in a gage glass.

4. (PG-60.1.1.2) When two independent remote water level indicators are in reliable operation (continuously indicating water level), the one required gage glass may be shut off, but shall be maintained in the serviceable condition.

Traditionally, sight glasses (water gauges) were fitted to the boiler drum. However, these can suffer from reliability issues, requiring intensive maintenance programmes. The drum is normally located a distance away from the control room, meaning that a secondary form of surveillance equipment is needed to report the level back to the engineering team. For these devices to be used effectively, they must be monitored 24 hours a day, 365 days a year. Mechanical/optical methods are regularly used for measuring levels within vessels, but the drawback with such devices is that they are susceptible to wear, and therefore also need regular checking and maintenance. This increases maintenance costs and with 24/365 operation, downtime for such maintenance is not always possible. This leads to insufficient checks and subsequent reliability issues. Sight glasses are still in use today, but only as the final verification method of drum level if all other methods are unavailable.

The power industry therefore demanded reliable dual redundant level monitoring technology, and customer-led development saw the birth of electronic steam/water gauging systems. Emerson was at the forefront of this technology, and its Mobrey™ Hydrastep electronic gauging system is seen by many as an industry standard. These systems consist of a number of electrodes installed within a water column attached to the steam drum. The electrodes act as the 'seeing eye' above and below the normal water level. Electrodes are arranged on each side of the column and connected to an electronics unit by separate specialist cables. This arrangement provides redundancy against failure in any part of the system.

The principal of measurement is very straightforward. The electronics are constantly looking for a change in resistance with respect to ground. A step change in resistivity between two adjacent electrodes identifies the water level. Using this device, the end user is able to set alarms and trips to aid the engineering team. Alarm relay outputs deliver high- and low-level alarm indications or trips. Local and remote displays provide operators with high visibility of boiler levels. An alarm/trip also occurs should a fault occur within the system or its associated wiring or power supply. This fault-tolerant operation eliminates the need for routine testing. Fault conditions are also shown on the displays.

For applications requiring the detection of either steam or water, resistivity measurement is a proven technique. Using an electronic method to indicate water level, or to differentiate between the presence of steam or water, offers a very high level of system self-checking and integrity compared to mechanical methods since there are no moving parts. This greatly reduces the requirement for routine maintenance.

Protection is critical to plant safety, but false trips are also a major issue. Thus, not only must a system be completely reliable when it comes to detection and prevention of water in turbines, but it must also prevent nuisance trips that reduce plant efficiency and throughput. The reliability of these systems can be dependent upon the quality of the water in the system. Whilst this is usually clean, the presence of dirty water can foul the electrodes. However, in more sophisticated systems, this will not cause a fault or a trip. An independent report by Factory Mutual Research concluded that the probability of Emerson's Hydrastep missing an actual trip condition is less than one in 300 million. The probability of creating a nuisance trip is less than one in 10 million.

Reliable application

This superior reliability is well-demonstrated at an application in China. Electronic gauging systems provided the level indication and alarms for steam drums at a coal-fired power plant in Jiangsu. However, after less than two years of operation, they were experiencing leaking electrodes that caused false alarms and nuisance trips. This caused a loss in confidence that the existing alarm system would trip the boiler in the event of an alarm condition. The leaks were found to come through the seal between the electrode and the column, as well as through the electrodes themselves. The electrodes had to be replaced, but this task led to further wear on the threads, increasing the rate at which they leaked. The problem not only caused unnecessarily high maintenance costs, but also increased risk to personnel performing the maintenance on the high pressure and temperature system.

With reliability an increasing issue, the plant decided to replace the existing system with the Mobrey Hydrastep 2468 Electronic Gauging System for steam drum level measurement. The system has been installed in thousands of applications globally and has proven to be extremely reliable. A key feature of the system is that the electrodes comprise exotic metals and high-quality ceramics brazed under very specific conditions, which reduces the possibility of leaks. Two Hydrastep systems were installed on each drum, providing the outputs for Hi and Hi-Hi alarms to trip the boiler. Remote displays in the control room provide continuous level indication to the plant operators. Twelve months after installation, there have been no reported leaks, false trips or false boiler shutdowns. The time spent and cost of maintenance has been significantly reduced, the risk to workers is much lower, and there is now full confidence in the steam drum alarm system. CEA

Robin Hudson is the product and applications support manager at Emerson. Hudson has been with Emerson for close to 12 years giving customer support for all products manufactured at Rosemount Measurement Ltd in Slough, UK. Robin has gained in-depth product knowledge and field experience to become the Hydratect and Hydrastep specialist, and so is better able to support customers and to maintain and improve the products. Robin has a BSc from the Open University and always welcomes the opportunity to discuss any possible Hydratect and Hydrastep applications.