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On-Site Hydrogen Production Provides Multiple Benefits For Thermal Power Plant Operations.

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ON-LINE MEASUREMENTS ENHANCE GENERATOR PERFORMANCE

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ON-LINE MEASUREMENTS OF HYDROGEN PURITY AND MOISTURE CONCENTRATION (DEW POINT) ARE ESSENTIAL

for the efficient and safe operation of hydrogen-cooled generators. Without these critical measurements, the life of equipment, the safety of the plant and its personnel, and the efficiency of the generator system are compromised. Continuous monitoring of hydrogen purity and dew point provides a sense of comfort when the system is operating within specification, and offers an effective troubleshooting tool for identifying and correcting upset conditions. The costs associated with purchasing and maintaining accurate and reliable monitoring equipment for hydrogen and moisture concentrations within a turbine generator's cooling system are minimal, and certainly overshadowed when compared to the expenses incurred in their absence.

Honeywell's 4112 Dew Point and Temperature Transmitter

PROS AND CONS

In hydrogen-cooled generators, hydrogen is circulated through hollow conductors in the generator casing to remove the vast amount of heat that is created, primarily from the production of electric current. Hydrogen's excellent heat transfer characteristics, and its low molecular weight (density), facilitate effective heat removal from the generator and also promote maximum practical output ratings without requiring appreciable changes in generator size.

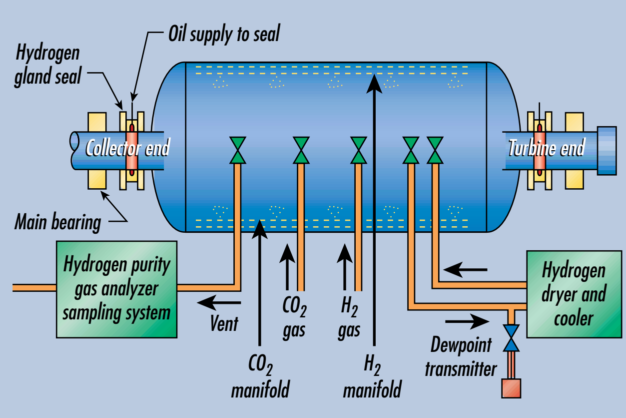
When a generator rotor rotates at high velocities in larger turbine generators, the turbine must overcome the resistance created by the atmosphere in the generator casing. The wasted energy used to overcome this resistance is given the term *windage loss*. By increasing the percent of hydrogen in the cooling system, and minimizing the presence of impurities such as air and moisture, the generator's windage losses are reduced, effectively increasing unit output. In addition, cooling of generator windings results in higher efficiencies and allows operation at higher power levels. Preliminary studies indicate that a one percent increase in hydrogen purity in a typical generator system results in daily operating savings of up to $1,000.

Though extremely effective for performing the tasks outlined above, hydrogen gas, and the cooling system in general, require close attention to ensure a safely operating generator system. Hydrogen-in-air mixtures are explosive between the concentrations of 4 and 74 percent. In an environment where hot surfaces and ignition sources are commonly present, maintaining hydrogen at safe and non-explosive levels is crucial for ensuring the safety of the plant and its personnel.

Moisture in a generator cooling system not only reduces system efficiency by diluting hydrogen purity, but also creates an opportunity for corrosion to occur, increasing the possibility for component failure, as well as a potential system catastrophe. The retaining ring on a turbine generator's rotor is the most highly stressed generator component. The intense stresses imposed on the ring require that it be made of a highstrength alloy that is also non-magnetic for purposes of reducing electrical losses. The retaining ring provides structural support to accommodate the centrifugal load developed on the copper end windings and blocking. Consequently, an essential objective of the cooling system must be to prevent corrosion of the retaining ring, thereby preserving structural integrity. Similarly, it is important to maintain the integrity of other highly stressed components, including separating rings, clearance rings and impeller rings.

Excluding moisture is difficult because water vapor can penetrate the hydrogen cooling system in a variety of ways, such as hydrogen cooler leaks, stator water system leaks, makeup hydrogen or turbine steam leaks into the generator casing. In addition, moisture infiltration and condensation can occur in the generator system during shutdowns and storage. The presence of moisture in the generator system accelerates the corrosion of the aforementioned highly stressed turbine generator components, leading to increased downtime and maintenance costs. Of greater concern is the fact that moisture threatens the safety of the generator system in general, as well as its operators.

FIGURE 1
HYDROGEN-COOLED GENERATOR SYSTEM



Staying Pure, Dry and Safe

In the startup phase of a hydrogen-cooled generator, the hollow cooling conductors, as well as the inside of the generator itself, contain ambient air and moisture. The air must be removed before introducing the hydrogen gas to prevent explosive mixtures of hydrogen and air. An inert gas, typically carbon dioxide (CO_2), is used to purge the air from the generator before introducing hydrogen to the system. On startup of the generator, CO_2 is introduced into the bottom of the generator housing, and the air is forced out at the top (Figure 1). When the CO_2 concentration reaches approximately 86 percent, hydrogen is introduced into the generator, forcing out the remaining CO_2. The hydrogen is added at the top of the generator and the CO_2 is exhausted from the bottom.

During normal operation, hydrogen gas circulates through the generator by way of the hollow cooling tubes. The hydrogen collects heat as it passes through the generator, and is then cooled further downstream, usually by water-cooled finned tubing or some other type of heat exchanger. Gland-seal oil leaks, as well as leaks in the circulation line and generator casing in general, can result in hydrogen purity degradation by allowing air and moisture to infiltrate into the system, while permitting hydrogen to escape. Since such leaks can lead to a drop in power output, as well as promote corrosion, it is imperative to continually monitor the hydrogen purity and dew point in the system to detect any hydrogen loss.

To counteract decreasing hydrogen purity levels from leaks into the generator system, pure hydrogen stored in nearby tanks is added to the system while diluted hydrogen is released to atmosphere. In extreme instances of air infiltration, the system can be configured so that pure hydrogen is continuously fed to the generator while contaminated hydrogen is continuously bled to atmosphere. To reduce moisture intrusion in the generator during normal operation, generator manufacturers often prescribe hydrogen dryers for their units to remove moisture, prevent corrosion, and avoid carrying corrosion products to the stator and rotor windings. Some manufacturers do not provide drying because they believe that dry hydrogen, provided by suppliers, is adequate to keep moisture out of the machine and maintain an adequate dew point to prevent condensation. However, with or without dryers, most generator manufacturers recommend moisture monitoring.

Generators are generally scheduled for an annual outage. During this shutdown, hydrogen gas must be removed to prevent a potential explosion hazard when mixed with air. To prepare for the outage, CO_2 gas is introduced at the bottom of the generator housing, forcing the hydrogen gas out of the top of the housing. Sufficient CO_2 is added to reduce the hydrogen content in the generator to below 3 percent. Once this low hydrogen concentration is reached, the generator frame can be opened and a fan used to expel the remaining CO_2 and hydrogen gases. This purging method also prevents the harmful asphyxiation effects of hydrogen and CO_2.

On-Line Measurement

Density and thermal conductivity are the two most common technologies used for measuring hydrogen and other gases (i.e. CO_2) in turbine generators. A measurement system, regardless of the technology involved, typically consists of a sensing assembly, control unit and sampling system. Fundamentally, the sensing assembly detects the gas concentration and transmits a signal to the control unit, which processes the signal and displays a reading. A sample system is recommended to provide the appropriate sample conditioning necessary for satisfying the specification requirements of the sensing assembly. A sample conditioning system should, at a minimum, include equipment to perform the following operations: reduce/regulate the sample pressure, filter contaminants such as dirt and gland seal oil, maintain the appropriate gas flow rates during normal operation as well as calibration, and allow easy configuration for sample, reference and calibration gases.

The density measurement is based on the fact that component gases of a mixture typically contain different densities, and therefore will cause different pressure differentials to be developed when passed across an orifice plate at a constant flow rate. A blower fan is used to create a constant flow, and the associated pressure differential developed is used by the control unit to calculate the hydrogen purity and report its value. To calculate the readings, the control unit uses preprogrammed algorithms relating pressure differential to percent hydrogen. In general, older density measurement system designs are regarded as unreliable, and newer systems have yet to be proven in the field.

Most hydrogen purity measuring systems in use today are based on thermal conductivity technology, which takes advantage of the fact that the components of a gas mixture possess varying degrees of ability to conduct heat. In fact, as was mentioned earlier, the primary reason for choosing hydrogen as a generator-cooling medium is its superior ability to conduct heat. This property of hydrogen makes thermal conductivity an extremely useful technique for detecting its presence in varying concentrations.

Honeywell's 7866 Hydrogen Purity Gas Analyzer

Independent of the technology employed, all hydrogen purity measurement systems should contain the ability to monitor all phases of the generator operating cycle. At startup, when the generator is being purged of ambient air with an inert gas (CO_2) before introducing hydrogen, a typical measurement system, switched to its percent-CO_2-in-air range, monitors the replacement of air with CO_2. At shutdown, the analyzer operates on its 0 to 100 percent CO_2-in-hydrogen range while monitoring the replacement of hydrogen with CO_2. Monitoring the various gas concentrations during purging operations enhances plant safety, and reduces the large volumes of wasted inert gas traditionally used to prevent unstable mixtures of hydrogen in air. During normal generator operation, when the cooling system contains mostly pure hydrogen, the analyzer, switched to its 100 to 75 percent hydrogen-in-air range, will detect any lowering of the purity of the hydrogen.

Unlike the limited number of technologies offered for measuring hydrogen purity, a number of technologies are currently employed for moisture detection. Aluminum oxide, chilled mirror, fog chamber, and capacitance (polymer) are a few of the popular technologies that have traditionally been applied to hydrogen cooling systems. Like most instrumentation, certain moisture measurement products provide a true advantage in certain applications, but fall short in others. An instrument that provides accurate and reliable information, requires minimum maintenance, and is easy to configure and calibrate is becoming more valuable in today's age of limited manpower. Applying this in the context of hydrogen-cooled generator applications, it is important to choose a moisture instrument that can measure accurately and continuously in hydrogen gas, under elevated pressures (typically up to 75 psig) and in the potential presence of contaminants such as lubricating oils.

Once an accurate and reliable dew point measurement is ensured, what does its reported reading mean in relation to the process? Dew point measurement is often considered "black magic" in the minds of users. Operators are often quick to blame an instrument for reporting false dew point readings rather than face the implications considered when assuming the readings to be correct. Could the dew point in the generator really be 40 F? When applied correctly, dew point measurements are extremely useful for ensuring proper system operation when reading within specification, and are effective for detecting system leaks, which lead to increased maintenance time and money. Until users are willing to invest the time required to fully understand moisture and its relation to their process, however, dew point measurements will remain undervalued. PE

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