

Online Gas Analysis of Hydrogen-Cooled Electric Power Generators

Process Overview

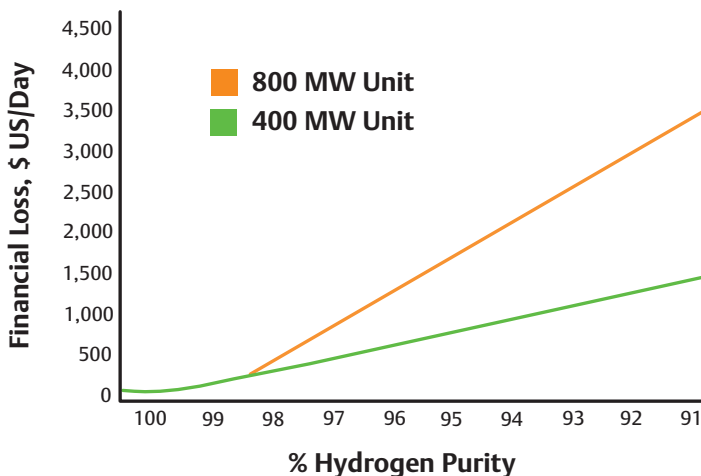
Early electric generators were air-cooled, but as generators became increasingly larger, the use of air as a cooling medium became inadequate. Larger generators produce more heat and require more intense cooling procedures. These larger generators also introduce other challenges such as windage losses caused by wind resistance and friction on the spinning generator shaft.

Helium used to be considered for cooling, but due to its low abundance and high cost, it has been replaced with hydrogen. Hydrogen is readily available and has a thermal conductivity that is higher than air, making it a very good cooling medium. Hydrogen has also a much lower viscosity than air. This significantly decreases the windage losses and ensures the efficiency of the generator.

Measurement Challenges

The main challenge with using hydrogen as a cooling medium is that it is explosive when mixed with air and exposed to an ignition source. However, hydrogen does not support combustion when it is in a nearly pure state (> 90%). The upper explosion limit is 75%. Using the right online gas analyzer for continuous monitoring of the gas cycle is critical to preventing fire hazards, ensuring the safety of the plant and personnel, and controlling the purity of hydrogen. A drop in hydrogen purity causes windage losses, higher power generation cost per megawatt, and reduced generator efficiency.

Figure 1 - Cost of Decreased Hydrogen Purity



Maintenance of a Hydrogen-Cooled Generator

Gas Analysis Measurements

Continuous online gas analysis is used in hydrogen-cooled electric power generators for the following purposes:

- **Generator Efficiency:** Maintaining a high concentration of hydrogen coolant increases the cooling efficiency of the generator (see Figure 1 for the cost of decreased hydrogen purity).
- **Plant and Process Safety:** Air in the hydrogen coolant can quickly lead to an explosive condition.
- **Personnel Safety:** Air must be present inside the generator before personnel can perform maintenance inside the generator.

Measurements need to be performed during normal operation and during start-up and shutdown purging operations. During normal operation, the hydrogen purity is monitored in an 80 to 100% H₂ range to detect air leaks or hydrogen supply problems. During the start-up of a hydrogen-cooled generator, air in the generator is first displaced with carbon dioxide.

After the first purge operation is complete, the generator is filled with hydrogen. During shutdown, typically for maintenance, the opposite scenario takes place. During start-up and shutdown, monitoring the carbon dioxide and hydrogen helps the operators minimize start-up and shutdown time, and keeps the maintenance operation safe since the analyzer reading indicates when the purge process is complete.

The Emerson Solution

Equipped with a thermal conductivity detector and a flameproof housing, the Rosemount X-STREAM Enhanced XEFD Continuous Gas Analyzer delivers two measurements to ensure the safety of the power plant and to maximize the efficiency of the generator. These measurements are:

- 0–100% H₂ in CO₂/air or 80–100% H₂ in air (adjustable)
- 0–100% CO₂ in air

Start-up Phase – Monitoring the Filling Process

Air in the generator must be displaced by a neutral intermediate gas before it gets filled with hydrogen to avoid explosions. The displacement of air by CO₂ and of CO₂ by H₂ must be monitored. This is required to ensure the purging process lasts long enough to avoid explosions and to limit the gas consumption to a minimal quantity.

- The first purge operation during start-up:
 - Ambient air is first replaced by CO₂ since mixing H₂ directly with air would produce an unsafe condition.
 - Measurement range is 0–100% CO₂ (with air as background gas)
- The second purge operation during start-up:
 - CO₂ is then safely replaced with H₂
 - Measurement ranges are 0–100% H₂ with special linearization, 0–40% H₂ (with CO₂ as background gas), 40–80% H₂ (extrapolation between air and CO₂ as background gas), 80–100% H₂ (with air as background gas)

Operation Phase – Monitoring the Operating Conditions

Hydrogen purity must be measured to avoid the generation of oxyhydrogen by leakage and penetration of air. The only possible impurity is air and therefore the measurement range is:

- 80–100% H₂ (with air as background gas)

Maintenance Phase

Breathing air must replace other gases before personnel can safely perform maintenance inside the generator.

- The first purge operation during shutdown for maintenance:
 - H₂ is first replaced with CO₂ since mixing air directly with H₂ would produce an unsafe condition
 - Measurement range is 0–100% H₂ with special linearization
- The second purge operation during shutdown for maintenance:
 - CO₂ is then safely replaced with breathing air
 - Measurement range is 0–100% CO₂ (with air as background gas)

Analyzer Setup Options

The Rosemount X-STREAM Enhanced XEFD Continuous Gas Analyzer is built in a flameproof enclosure certified for installation in Zone 1, Zone 2, and Class I Division 2 hazardous areas without the need for pressurized systems. It comes standard with two measurements and two analog outputs:

- The first measurement for 0–100% H₂ in CO₂/air is set to 80–100% H₂ in air. Operators can switch manually to 0–100% H₂ in CO₂/air. Switching between both ranges of the first measurement can also be achieved automatically. The analyzer is set up to indicate the measurement on digital output.
- The second measurement detects 0–100% CO₂ in air.

Optionally, a three-measurement configuration is also available and includes a third analog output:

- 80–100% H₂ in air
- 0–100% CO₂ in air
- 0–100% H₂ in CO₂/air



Rosemount X-STREAM Enhanced XEFD Continuous Gas Analyzer

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00800-0300-3975 Rev AA