On-Line Gas Analysis of Hydrogen-Cooled Generators

Application

Emerson Process Management offers Rosemount Analytical gas analyzer technology to provide on-line analysis of hydrogen-cooled electric power generators to improve both profitability and operational safety.

Background

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

Helium was considered for cooling, but helium was not found in abundance and, as a result, cost much more than other gases. Hydrogen, however, was readily available and had a thermal conductivity much higher than air which made hydrogen a very good cooling medium. Additionally, hydrogen had a much lower viscosity than air. This significantly decreased the windage losses, thus increasing the efficiency of the generator. Around 1937, hydrogen replaced air as the primary gas used to remove heat from stator windings, rotor windings, and stator core iron in larger generators.

However, hydrogen poses fire hazards that are not a concern with air or helium. Fortunately, hydrogen does not support combustion in a nearly pure state (> 90 %) with a balance of air. With proper operation, including the use of on-line gas analysis, fire hazards can be almost completely eliminated.

Gas Analyzer Application

On-line gas analysis is used in hydrogen-cooled generators for the following purposes:

- Commercial: maintaining a high concentration of hydrogen coolant increases the cooling efficiency of the generator (For cost of decreased hydrogen purity, see Figure 2).
- Safety - Explosion: air in the hydrogen coolant can quickly lead to an explosive condition.
- Safety - Maintenance: air must be present inside the generator before personnel can perform maintenance inside the generator.

Fig. 1: *Maintenance of a Hygrogen-cooled generator.*

Measurements need to be done during normal operation and during start-up and shutdown purging operations. During normal operation, the hydrogen purity is monitored in an 80 to 100 % H_2 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 they know from analyzer reading when the purge circle is complete.

A thermal conductivity analyzer set up with two measurements is typically used for this application:

- Measurement 1: 0 -100 % H_2 in CO_2/air or 80-100 % H_2 in air (adjustable)
- Measurement 2: 0 -100 % CO_2 in air

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Start-Up Mode

Hydrogen must replace other gases for efficient generator operation.

- First purge operation during start-up:
  - Ambient air is first replaced by CO_2, since mixing H_2 directly with air would produce an unsafe condition.
  - Measure 0 -100 % CO_2 (with air as background)
- Second purge operation during start-up:
  - CO_2 is then safely replaced with H_2
  - Measure 0 -100 % H_2 with special linearization
    - 0 - 40 % H_2 (with CO_2 as background gas)
    - 40 - 80 % H_2 (extrapolation between air and CO_2as background gas)
    - 80 - 100 % H_2 (with air as background gas)

Operation Mode

Hydrogen purity needs to be measured.

- Measure 80 - 100 % H_2 (with air as background gas)

Maintenance Mode

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

- First purge operation during shutdown for maintenance:
  - H_2 is first replaced with CO_2, since mixing air directly with H_2 would produce an unsafe condition
  - Measure 0-100 % H_2 with special linearization
- Second purge operation during shutdown for maintenance:
  - CO_2 is then safely replaced with breathing air
  - Measure 0-100 % CO_2 (with air as background gas)

Setup Options

The analyzer comes standard with two measurements and two analog outputs. Measurement 1: 0 -100 % H_2 in CO_2/air is zoomed to 80-100 % H_2 in air. Customers can switch manually to 0 -100 % H_2 in CO_2/air. Switching between both ranges of measurement 1 can also be done automatically.

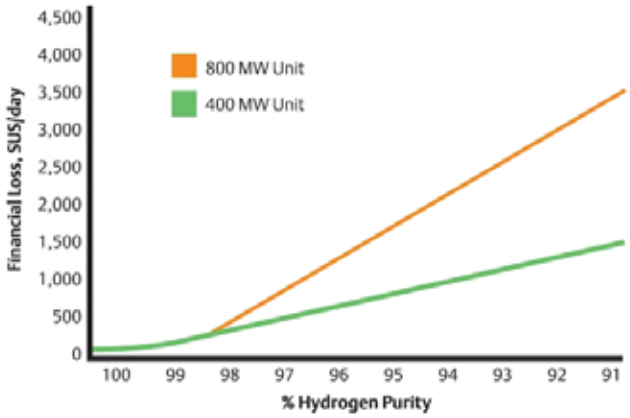

Fig. 2: *Cost of decreased hydrogen purity.*

The instrument is setup to provide a zoom indicator on digital output 4, so the customer can monitor the zoom status. Measurement 2 detects 0-100 % CO_2 in air.

Optionally, a three-measurement configuration is also possible:

80-100 % H_2 in air
0-100 % CO_2 in air
0 -100 % H_2 in CO_2/air

For this configuration a third analog output has to be ordered.

Emerson can supply either a Rosemount Analytical X-STREAM flameproof analyzer or an X-STREAM purged/pressurized analyzer for this application. The analyzer can be used to ensure power plant safety, and to maximize the efficiency and profitability of running the generator.

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