Monitoring hydrogen cooled turbogenerators in power plants (fossil-fired, hydro, nuclear)

Components to be measured
- CO₂ in air
- H₂ in CO₂
- H₂ in air

ABB solutions
- EL3060-Caldos27, Zone 1
- AO2000-Caldos27 SC, Zone 2
- EL3000-Caldos27, GP
- AO2000-Caldos27, GP

Measurement made easy

Introduction
In power generation, different cooling agents are used to cool the generators. In the past, air was often used for this purpose, but with an increase in the generators dimensions as well as the improvement of process efficiency, hydrogen is being used more often to cool the generators. Hydrogen enables the plant operator to reduce windage losses and increase the efficiency, especially the power limit.

Windage losses occur due to the power requirements for circulating the cooling agent and the friction of the rotor. As windage and gas friction losses are nearly proportional to the density of the cooling agent, they are considerably reduced by using hydrogen which is approximately 14 times lighter than air and thus the efficiency factor is improved.
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Efficiency, is increased by the seven times higher thermal conductivity of hydrogen in comparison to air. This renders an increase in thermal utilization of the machine, i.e. a higher efficiency can be reached from a certain model when operated with hydrogen cooling instead of air, without an increase in the winding temperature.

The absence of oxygen in H₂-cooled generators has two further advantages: winding fires are nearly impossible and ozone or nitrous acid, which can be generated by glow-discharge, which would destroy the insulation, cannot be generated.

A disadvantage of using hydrogen as a cooling agent, is that hydrogen is combustible and explosive when mixed with air, especially when the H₂-concentration lies between 4 to 75 Vol%. Therefore, the air in the generator has to be displaced by a neutral intermediate gas before being filled with hydrogen to avoid the generation of oxyhydrogen gas.

For example, carbon dioxide is used as intermediate gas and is blown into the bottom of the generator. CO₂ is heavier than air and the generator is slowly filled from the bottom up. Air escapes through the H₂-pipes on top of the generator and flows into the exhaust vent. The filling procedure is continued until the escaping CO₂-air mixture contains more than 95 Vol% CO₂. This gas mixture is no longer explosive even in the case of an overfilling with H₂.

Because of its lower density, the hydrogen is filled from above until a sufficient degree of purity (96 to 98 Vol% H₂) is achieved. The CO₂ escapes through the exhaust piping into the open air.

During normal operation H₂ is continuously blown in, to maintain the pressure and purity of the gas in the generator.

The generator is emptied in the same way as it is filled, i.e. hydrogen is not directly dispelled by air but by CO₂ as the neutral intermediate gas.
Motivation
To avoid oxyhydrogen-gas explosions in hydrogen cooled Turbo-Generators during filling and operation, and to control the purity of the hydrogen, continuous monitoring of the gas cycle is required. Additionally, to increase plant performance and control generating cost per megawatt, turbo generators must perform with optimum efficiency. A drop in hydrogen purity causes additional windage losses and consequently reduces generator efficiency.

Phase 1: Monitoring the filling process
During the filling process the displacement of air by CO₂ and of CO₂ by H₂ has to be monitored. This is required to ensure a purging process lasts long enough to avoid explosions and to limit the gas consumption to a minimal quantity. The measuring ranges are as follows:
0 to 100 Vol% CO₂ in air and
0 to 100 Vol% H₂ in CO₂

Phase 2: Monitoring the operation conditions
During operation, the purity of the hydrogen has to be controlled to avoid the generation of oxyhydrogen by leakages and penetration of air. The only possible impurity is air and therefore the measuring range are:
100 to 90 (80) Vol% H₂ in air

Phase 3: Monitoring the discharge process
The displacement of H₂ by CO₂ and of CO₂ by air has to be monitored during the discharge process. The same measuring ranges as for the filling process are applicable.
100 to 0 Vol% H₂ in CO₂ and
100 to 0 Vol% CO₂ in air

ABB solution, EL3060
EL3060 is built in a completely flameproof enclosure in accordance with all the requirements of Category II 2G and can be used, due to its high safety standards, in plants with potentially explosive gas atmospheres in Zone 1 and Zone 2.

The EL3060-Caldos27 is convincingly compactly built. The control unit, the power supply and the thermal conductivity analyzer are placed all together in a compact housing. The control unit is provided with a terminal box with increased safety. Without compromising the hazardous area protection customers can safely and easily connect signal cables for analog output and status signals. The analyzer can be directly operated through an explosion proof glass panel via touch-sensitive keys without further equipment and without having to open the housing.

To monitor all three possible process phases the EL3060 provides different ways to change between the measuring components and to provide a feedback of the current measuring component
• via Display in front of the analyzer
• via digital in- and outputs
• via Modbus (Modbus TCP IP) interface
This enables the analyzer to be easily operated externally via a PC, PLC or process control system.

As an alternative if a General Purpose (GP) or Zone 2 installation is required (not often the case) the solution can be also configured with a standard EL3000 or AO2000, as well as an AO2000 Safety Concept (SC) for installation in Zone 2.

Customer benefits
• secure plant and process safety
• improve overall generator efficiency