

Background information

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Proven automation solutions

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Hydrogen: Safe from production through to use

Ostfildern, 21 May 2025 - **As an energy carrier, hydrogen has huge potential worldwide for climate protection, and has a key role to play in achieving climate goals. However, there are risks involved in the manufacture, transportation, storage and ultimately the use of hydrogen. That's because the gas is colourless and odourless, while at the same time highly flammable. Holistic safe solutions from Pilz offer protection for the energy carrier's entire added value chain. They ensure safe, dynamic monitoring of process variables and entire process sequences. They contribute to making hydrogen not just clean, but also Safe and Secure.**

Hydrogen has a wide range of application options: sustainably produced hydrogen, so-called “green hydrogen”, plays an important role in energy-intensive production facilities, such as chemical or steel production, as it can replace fossil fuels and reduce CO₂ emissions. It can also be stored and converted back into electricity when needed or used as fuel for fuel cell vehicles. Hydrogen presents opportunities and risks simultaneously. It is easily inflammable and highly explosive, even if only small amounts are mixed with air – ignition is possible when the hydrogen content in the air is just four percent. For this reason, air and hydrogen must not be mixed in an uncontrolled manner, to avoid the risk of ignition due to sparks or heat. Safe production, handling and use all require suitable safety systems.

Safety technology requirements for hydrogen

Gas tightness, robustness of shut-off devices as well as pressure resistance and tightness of pipes, sensors and valves are particularly important in the hydrogen industry. That's because a gas leak, excess pressure or a leaky valve can have major consequences for human, plant and environment. Accordingly, the solutions to safety tasks frequently involve particular material properties and mechanical dimensioning: the more robust the shut-off valves, for example, the safer they are to use. Ultimately, the highest process pressures are required for hydrogen fuelling of vehicles or trains.

Hydrogen is mainly stored in a gaseous state under high pressure – between 200 and 900 bar. This will increase the energy content per cubic metre. Gaseous hydrogen is very volatile. As one of the lightest elements, it spreads upwards very quickly and mixes with air. It can be problematic if hydrogen accumulates within closed structures or buildings, as that increases the risk of ignition or explosion. Because hydrogen is highly flammable, even small sparks or heat sources can lead to an explosion. Therefore even the smallest leaks in hydrogen pipelines, valves, screw fittings and tanks present a serious risk. Also, hydrogen is a colourless and odourless gas. Hydrogen fires are often difficult to locate and extinguish as a result.

There are advantages to not limiting safety solely to a static status check. Tested and available safety principles from automation and functional safety can be applied to the hydrogen industry. These solutions help to consider safety always as an overarching monitoring function for components and their functional relationship within the process chain. In addition to the components' static safety features, safe, proven automation solutions can take on responsibility for dynamic pressure and temperature monitoring or safe adherence to

the load limits of downstream structures, for example. The control systems from Pilz reliably detect gas leaks through the evaluation of gas detectors and safely monitor temperature, pressure, fill level, voltage, current, and also the emergency stop. They detect faults within milliseconds and initiate pre-defined safety reactions that protect human and plant.

Safe production: Electrolysis and steam reforming

Hydrogen can be produced in various ways. With electrolysis, electrical current is used to split water into its component parts, producing gaseous oxygen and hydrogen. The different electrolysis processes require different safety considerations. Some processes need high pressures and temperatures, which must be monitored and controlled in order to avoid accidents. With PEM electrolysis, for example, an overpressure relief valve is an important safety mechanism, whereby the valve opens automatically and excess hydrogen can escape. The safe small controller PNOZmulti 2 from Pilz is proven across sectors when it comes to monitoring safety functions – such as gas pressures. This is primarily due to the high measurement accuracy of these safety-related values, which are used as the basis for initiating a safety measure – this makes plant components that use the safe small controller particularly efficient and safe.

In addition to pressure monitoring, other safety functions required in the hydrogen production process can also be monitored with high precision. These include temperature and fill level, as well as gas and leakage detection. On electrolyzers, the PNOZmulti 2 also monitors the rectifier voltage and current. This is important because

fluctuations or excess voltages, for example, can deteriorate the cells more quickly and lead to premature wear.

Steam reforming is another method of producing hydrogen from carbon-based energy carriers and water. In the process, a fuel such as natural gas or methanol, for example, reacts with steam under high temperatures and pressures. Hydrogen and carbon dioxide are produced. This procedure requires high temperatures, which are achieved using burners. The standard “ISO 16110-1:2007: Hydrogen generators using fuel processing technologies - Part 1: Safety” explains all the significant hazards such as EMC, electrical aspects, high-pressure aspects, prevention of explosions etc., regarding the safety of hydrogen production from fossil fuels. The small controller PNOZmulti 2 Burner and the automation system PSS 4000 can not only monitor temperatures and pressures safely, but can also take over the safe control and monitoring of burner management.

Safe, efficient storage and transportation

Once produced, hydrogen can be stored and transported in various ways, depending on the production process, the travel distance and the needs of the end user. In compressed form, the energy carrier can be transported by rail, water or road, for example. To enable hydrogen to be transported safely and efficiently, it must first be stored, using compressed gas storage for example. In this process, the energy carrier is highly compressed and stored in special high-pressure tanks. As hydrogen is a very light and volatile gas, pressure monitoring is required to store it efficiently. Special safety precautions are essential here, as pressures that are too high or too low can have serious consequences.

A liner for hydrogen is an important component in hydrogen pressure vessels. It forms the inner layer of the tank and is used to store and seal the hydrogen safely. The pressure difference between the inside and the outside changes significantly during processes in which the pressure changes – for example when the tank is filled, when hydrogen is removed or even during temperature fluctuations. These rapid pressure changes can cause stresses in the composite material if they occur repeatedly. The result: delamination of the material (the individual layers of the material separate from each other), an impaired service life for the pressure vessel as well as leakages and, in the worst case, even explosions. To protect the hydrogen tanks and in particular the people in the vicinity of the transfer points, special safety precautions are required when filling and emptying the tanks.

The safe, industry-proven small controller PNOZmulti 2 from Pilz monitors these transfer processes reliably with failsafe analogue value processing – and stops a process in the event of an error. In Bremerhaven, Germany, GP JOULE counts on safety solutions from Pilz. The energy company converts excess electricity into CO₂-neutral hydrogen, stores it in tanks on special lorry trailers and delivers the highly flammable gas to hydrogen refuelling stations within the city. Here, vehicles belonging to Bremerhaven Bus, among others, are refuelled with green energy. Loading and unloading of the high-pressure mobile transport containers is equally simple, fast and, above all, safe at all transfer points.

High level of safety

With pressure and temperature monitoring as well as filling and emptying speed, hydrogen tank manufacturers specify limits for their

filling and emptying. Maintaining these values in each operating state is ultimately the task of the pressure control valve and the control and monitoring function in the dispenser (hydrogen refuelling unit). A major task, because this hydrogen source is ultimately also responsible for the safety of the so-called hydrogen sink, i.e. the storage tank into which the hydrogen flows (such as a vehicle). The hydrogen sink does not have an electrically controllable shut-off valve, which could actively limit the pressure or flow rate. That makes it difficult for safety-related data exchange between the hydrogen source and sink. A safety controller on the hydrogen source side protects both sides and therefore the entire filling or emptying process.

With pressure ramp monitoring (gradient monitoring), changeable process variables can be controlled safely and any anomalies or errors can be detected at an early stage. The safe small controller PNOZmulti 2 uses failsafe analogue value processing to monitor compliance with relevant parameters in respect of critical limit values for pressure and temperature, as well as the speed at which the hydrogen is loaded and unloaded. In detail, the system includes the base unit PNOZ m B1 with several analogue value input modules, which guarantee the required high resolution with low theoretical error deviation, and a relay output module to control the safety valves. Fieldbus interfaces can also be extended to enable a simple exchange of diagnostic data with the process controller. The “Safe ramp monitoring” block integrated in the software tool PNOZmulti Configurator keeps a reliable eye on the limit parameters specified by a storage tank for pressure monitoring. If a value is exceeded or undershot, the safe small controller PNOZmulti 2 triggers a required reaction – closing a valve or throttling the output of a compressor, for

example. A PNOZmulti 2 analogue input achieves a safety-related accuracy of 1 per cent. For example, if a pressure range of 0 to 1000 bar needs to be monitored, the measurement deviation at a measuring range of 1000 bar is only 10 bar. In comparison, the measurement deviation would already be 50 bar if the safety-related accuracy of a safe analogue input was “only” 5 percent, for example. As a result, precise limit value setting with dynamic limit value monitoring is possible up to safety level SIL 3 in accordance with IEC 62061.

Fill up reliably at the hydrogen refuelling station

One important application area for hydrogen is powering vehicles. For hydrogen to be used as fuel in combustion engines, the appropriate infrastructure is needed. That’s why hydrogen refuelling stations (HRS) are key for the development of hydrogen mobility. A hydrogen refuelling station comprises a compression area in which the gas can be compressed up to 1000 bar, a cooling system, high-pressure storage tanks and the fuel pump. The setup and management of a hydrogen refuelling station is approved by the local authorities and is subject to the requirements of national or regional laws. Safety functions that must be considered at the hydrogen refuelling station include hydrogen leak, flame and smoke detection as well as temperature and pressure monitoring. In France, the automation system PSS 4000 from Pilz guarantees safety when hydrogen is dispensed at more than 10 public filling stations. Pilz France has been working there with the company Hydrogen Refueling Solutions (HRS) since 2023. Thanks to the decentralised structure and decentralised failsafe analogue inputs of the PSS 4000, the entire system can be built in a modular design, with short cable routes.

Functional safety requires Industrial Security

With digital networking and the decentralised structure of plants and systems in the hydrogen industry, the issue of Industrial Security is becoming increasingly important. This concerns the security of control networks in production and industrial plants in factory automation and process control. Potential vulnerabilities must be detected and rectified early, to prevent unauthorised access to the control network. One example is remote access to a container for hydrogen production, which checks the system status. If there is a risk of unauthorised changes to the safety-related parts of the system through this connection, then this plant section must be especially safeguarded. Because it guarantees safe operation. Systems for access and permission management, such as I.A.M. (Identification and Access Management) from Pilz, provide support from user authentication to operating mode selection, or data and network security to access management.

Holistic approach to Safety and Security

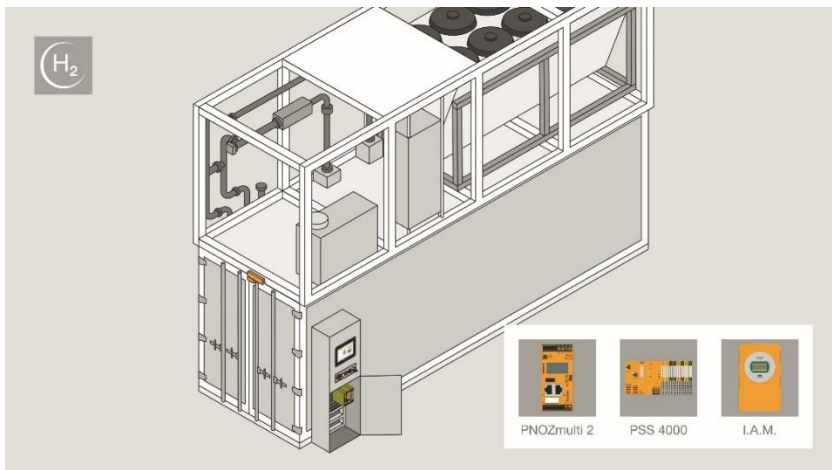
Automation solutions can be a valuable addition to the classic, mechanical safety features of the hydrogen industry. That's because functional safety always considers the entire lifecycle of safety devices. A continuous, systematically functional safety assessment protects human, plant and environment – starting from the production of the energy carrier, through to its use at the hydrogen refuelling station. Also, Pilz firmly believes that only a holistic approach to Safety and Security guarantees comprehensive protection. Because Security protects the availability of plant and machinery from manipulation and misuse.

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Photographic material:



Caption: Functional safety during electrolysis is implemented, for example, using safe analogue inputs on the safe small controller PNOZmulti 2 or the automation system PSS 4000. Systems for access and permission management are also available, in order to prevent manipulation of any kind. **Copyright:** © iStock.com/jeremyiswild, © Pilz GmbH & Co. KG

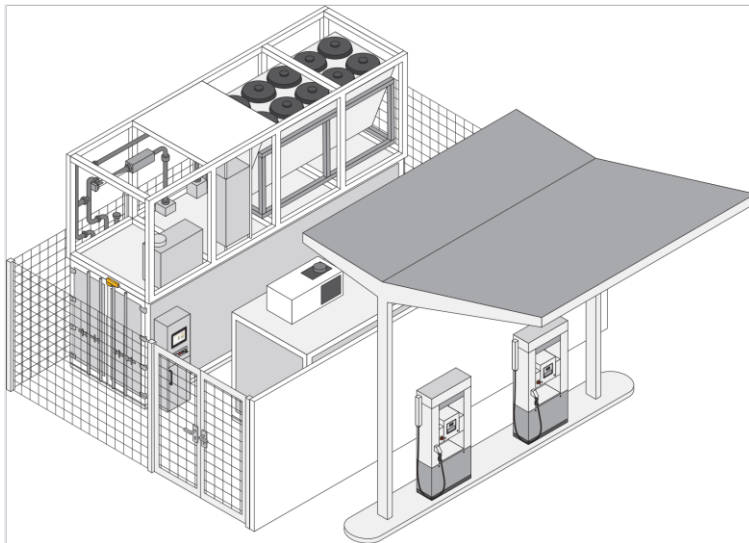


Caption: Electrolysers for the production of hydrogen - Safe and Secure monitoring with automation systems from Pilz **Copyright:** Pilz GmbH & Co. KG



Caption: Typical safety functions at a hydrogen refuelling station are hydrogen leak, flame and smoke detection as well as temperature and pressure monitoring.

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Caption: Avoiding explosive atmospheres is a key instrument in protecting against explosions at hydrogen refuelling stations. Early detection, fast leak tracing and the implementation of appropriate measures are important. **Copyright:** Pilz GmbH & Co. KG

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Pilz – The Spirit of Safety

Pilz is a global supplier of products, systems and services for automation technology. As a pioneer of safe automation, Pilz creates safety for human, machine and environment. Founded in 1948, today the family business with its head office in Ostfildern is represented worldwide with 2500 employees in 42 subsidiaries and branches.

The technology leader offers complete automation solutions for Safety and Industrial Security on the machine. These include sensor, control and drive technology – as well as systems for industrial communication, diagnostics and visualisation. An international range of services with consulting, engineering and training completes the portfolio. Pilz solutions are used in many industries beyond mechanical engineering, such as intralogistics, packaging, railway technology, or the robotics sector for example.

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