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Proven automation solutions

Handling hydrogen safely

Ostfildern, May 2024 - **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, handling and use of hydrogen because the gas is highly flammable, as well as colourless and odourless. To protect humans and the environment, functional safety must be guaranteed when handling hydrogen. Tested and available safety principles from automation perform key roles across the whole hydrogen industry. They contribute to making hydrogen not just clean, but also Safe and Secure.**

Everyone is talking about hydrogen. The energy carrier plays a crucial role in the energy turnaround and climate neutrality. It is used in industry, for example, when steelmaking, in the glass industry, for mobility as fuel for transport vehicles or for electricity reconversion. 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 can be liquefied by cooling it to -253 degrees Celsius. In this form it is more transportable in hydrogen tanks, taking less space. Safe insulation not only protects against heat but also against contact with the environment. If hydrogen comes into contact with the skin in this cryogenic state or if the freezing vapour of liquid hydrogen is inhaled, this can lead to frostbite, hypothermia and lung damage. Alternatively, hydrogen can be 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, valve 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 also 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 automation solutions can accept 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.

Safety from production through to use

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. If the pressure in the tank is too high, an overpressure relief valve is activated, for example, whereby the valve opens automatically and excess hydrogen can escape. Gas and flame detectors are important because they immediately recognise escaping gas and flames, so that safety measures can be initiated quickly – these include safeguarding of the danger zone or also the emergency stop, for example. Load fluctuations can also occur during electrolysis, depending on the electrolysis process. For this reason it is important to guarantee as constant an electrical supply as possible. That's because failure of the electrical section not only interrupts the electrolysis, but ultimately increases the risk of explosion as well. The safe small controller PNOZmulti 2 from Pilz is

proven across sectors. In functional terms, the configurable small controller PNOZmulti 2 is positioned between safety relays PNOZ and large, programmable control systems in the automation system PSS 4000. The small controller uses safe analogue inputs and the flexibility of the software tool to control and monitor all the necessary safety functions such as pressure, temperature or fill level.

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 even methanol, biogas or biomass, for example, reacts with steam under high temperatures and pressures. The oxygen content of the steam leads to partial oxidation of the fuel, and hydrogen and carbon monoxide are produced. This procedure requires high temperatures, which are achieved using burners. The small controller PNOZmulti 2 Burner and the automation system PSS 4000 can take over the safe control and monitoring sequence of a classic burner management system, but that’s not all. It can also undertake the control and safety monitoring of the production plant or machine in which the thermal process is integrated.

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 both compressed and liquid form, the energy carrier can be transported by rail, water or road, for example. The choice between compressed and liquid hydrogen depends on the specific requirements and the infrastructure. Transport by ship is suitable for the international import and export of hydrogen. Large quantities can be transported over long distances via pipelines.

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 currently 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 the increasing digital networking of plants and systems in the production and application of hydrogen, Industrial Security is an important consideration alongside functional safety. The objective of Industrial Security is to guarantee the availability of plant and machinery and the integrity and confidentiality of machine data and processes. Industrial Security describes the protection of production and industrial plants from manipulation or misuse. Security used to be the task of Information Technology (IT) in the form of IT Security. Today, production and industrial hydrogen plants are also highly interconnected using Information Technology. It is easier for attackers

to penetrate automation and control systems, manipulate them and even endanger safety (machinery safety). This means that even staff who are not IT experts are confronted with potential hazards. Industrial Security deals with the security of control networks in production and industrial plants in factory automation and process control.

Attackers often use existing vulnerabilities to penetrate control networks or disrupt processes. Potential vulnerabilities must be detected and rectified early, to prevent attackers accessing the control network. If an attacker succeeds in exploiting a vulnerability, the consequences for the company can be devastating, One example is a remote connection to a container for hydrogen production, to check the system status. This connection must be protected if this remote connection means that the safety-related part of the system can be controlled or modified without authorisation. The SecurityBridge industrial firewall from Pilz prevents this. Within the control network, all connections between the engineering, diagnostic or configuration tools and the controllers are protected against manipulation and enable secure external connections. With the access permission system PITreader and corresponding RFID transponder keys, the plants can be protected against unauthorised access, and access permissions can be controlled individually and reliably. That's because all operator actions can only take place once permission has been checked and approved.

Holistic approach to Safety and Security

For optimum use of hydrogen as an energy carrier, all the cogs must fit together. 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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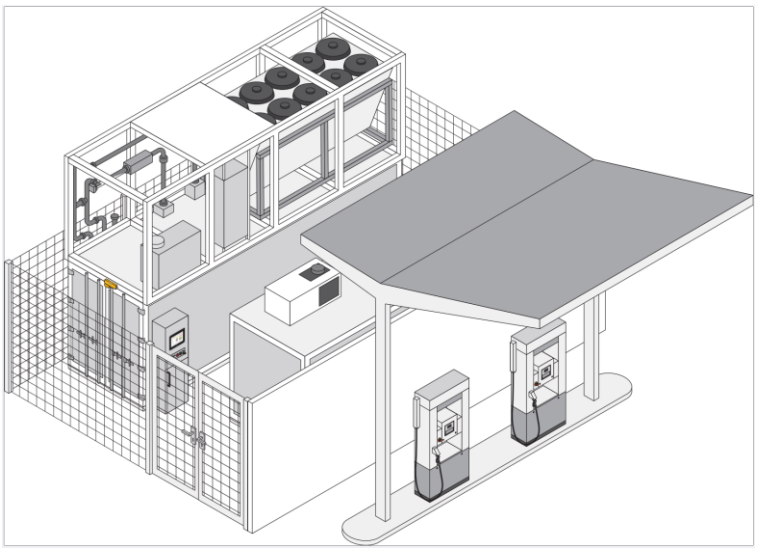
Photographic material:

Fig 1.



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.
(Photo: © Pilz GmbH & Co. KG)

Fig. 2: F_A_Hydrogen_refuelling_station_iSt1494263745_cold1

CAPTION: Typical safety functions at a hydrogen refuelling station are hydrogen leak, flame and smoke detection as well as temperature and pressure monitoring. (Photo: © iStock.com/Scharfsinn86, © Pilz GmbH & Co. KG)

Fig. 3: F_A_Hydrogen_production_electrolysis_iSt1469692762_cold1

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.
(Photo: © iStock.com/Scharfsinn86, © Pilz GmbH & Co. KG)

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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