BECKHOFF New Automation Technology

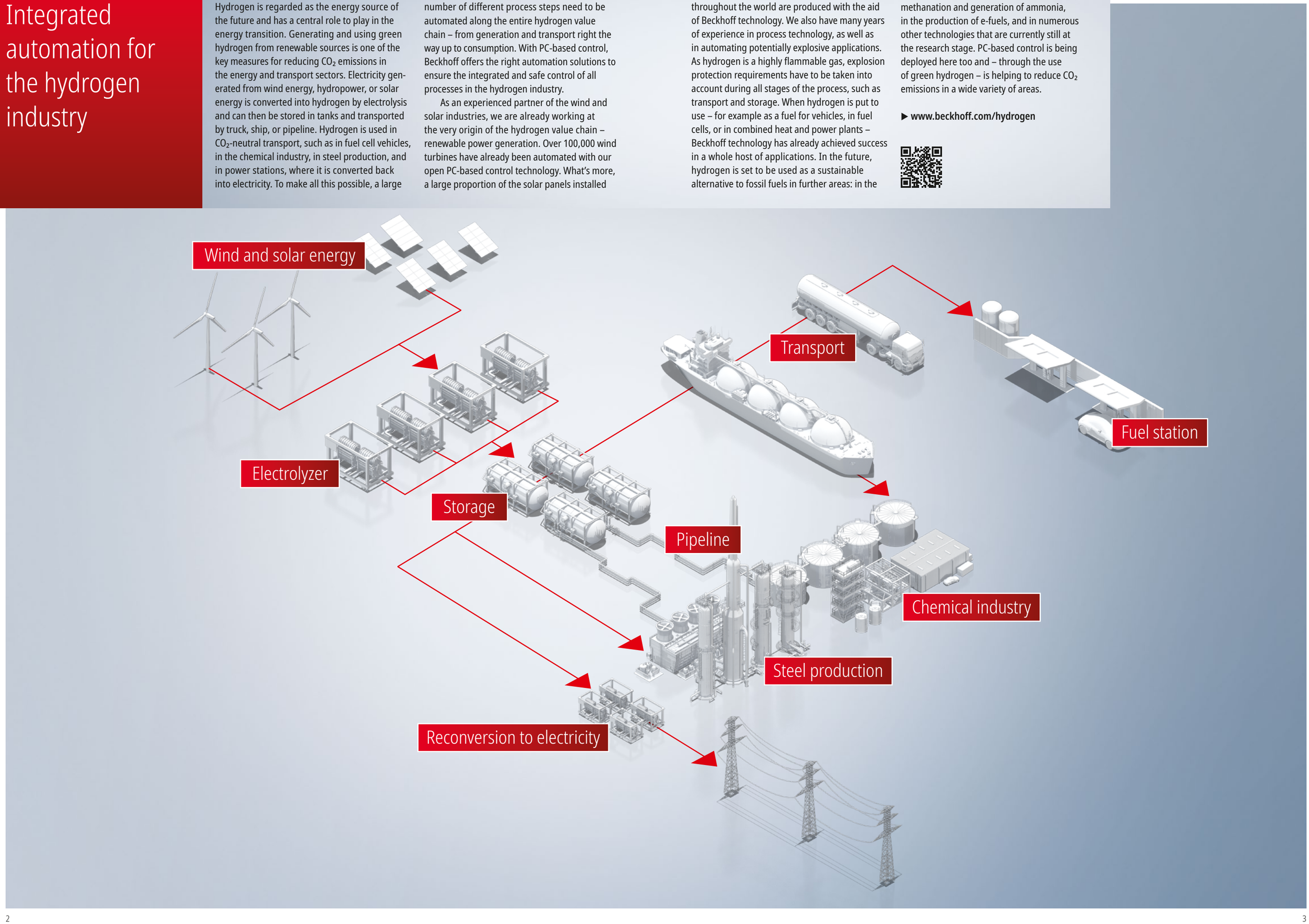
Efficient, flexible, safe: PC-based control for the hydrogen industry

Integrated automation for the hydrogen industry

Hydrogen is regarded as the energy source of the future and has a central role to play in the energy transition. Generating and using green hydrogen from renewable sources is one of the key measures for reducing CO_2 emissions in the energy and transport sectors. Electricity generated from wind energy, hydropower, or solar energy is converted into hydrogen by electrolysis and can then be stored in tanks and transported by truck, ship, or pipeline. Hydrogen is used in CO_2-neutral transport, such as in fuel cell vehicles, in the chemical industry, in steel production, and in power stations, where it is converted back into electricity. To make all this possible, a large number of different process steps need to be automated along the entire hydrogen value chain – from generation and transport right the way up to consumption. With PC-based control, Beckhoff offers the right automation solutions to ensure the integrated and safe control of all processes in the hydrogen industry.

As an experienced partner of the wind and solar industries, we are already working at the very origin of the hydrogen value chain – renewable power generation. Over 100,000 wind turbines have already been automated with our open PC-based control technology. What's more, a large proportion of the solar panels installed throughout the world are produced with the aid of Beckhoff technology. We also have many years of experience in process technology, as well as in automating potentially explosive applications. As hydrogen is a highly flammable gas, explosion protection requirements have to be taken into account during all stages of the process, such as transport and storage. When hydrogen is put to use – for example as a fuel for vehicles, in fuel cells, or in combined heat and power plants – Beckhoff technology has already achieved success in a whole host of applications. In the future, hydrogen is set to be used as a sustainable alternative to fossil fuels in further areas: in the methanation and generation of ammonia, in the production of e-fuels, and in numerous other technologies that are currently still at the research stage. PC-based control is being deployed here too and – through the use of green hydrogen – is helping to reduce CO_2 emissions in a wide variety of areas.

▶ **www.beckhoff.com/hydrogen**



The Beckhoff system: Modular and scalable control technology

For more than 40 years, Beckhoff has been using PC-based control technology to implement open and flexible automation systems in a wide variety of applications. Through the consistent bundling of control intelligence in the software and the use of established standard technologies in the IT and automation environment, PC-based control combines a full range of functions – including the PLC, motion control, HMI, and measurement technology – in one system.

The core of PC-based control is a powerful Industrial PC. Beckhoff's scalable industrial PC portfolio offers hardware solutions with performance levels and designs that can be perfectly tailored to any application. These industrial PCs are suitable for a wide range of applications: as a central or decentralized element of plant automation, as an HMI in the field, or as an edge device for IoT scenarios. Ultra-compact, they offer high computing power in a small design, allowing application scenarios to be implemented in a way that saves space. Panels and panel PCs facilitate visualization and operation directly at the plant. Embedded PCs or fieldbus couplers with the modular I/O level allow terminals from the Beckhoff I/O range to be directly connected, in turn enabling sensors and actuators to be linked to the control system with ease. The diversity of digital and analog signals in the extensive I/O portfolio also simplifies the cost-effective system integration of all functionalities – from measuring technology to application-specific safety solutions. Owing to numerous certifications in accordance with ATEX, IECEx, and NEC/CEC, I/O components can also be used in zone 2 and Class I, Division 2 hazardous areas, as can Embedded and Panel PCs.

We provide a central engineering and control platform with TwinCAT automation software. In addition to performing classic PLC processes, TwinCAT can be expanded to include numerous functions, such as plant visualization, secure cloud connection via TwinCAT IoT, or the use of analysis functions via TwinCAT Analytics. Entire drive systems can also be implemented using Beckhoff drive technology and the TwinCAT automation software's motion control system. Used in combination with servomotors featuring One Cable Technology, servo drives reduce the amount of work involved in installation compared to conventional two-cable wiring. With a power and feedback system provided in a single standard motor line, material and commissioning costs can be reduced significantly.

System-integrated solutions from Beckhoff offer an efficient alternative to conventional approaches and are ideal for use in the hydrogen industry. PC-based control enables full automation of machines and plants along the entire hydrogen value chain, from production and transport to the refueling station.

Efficient automation optimizes electrolyzers

As hydrogen is increasingly being used as an energy source or raw material in the chemical industry, demand for it is continuously rising. At present, this can largely be satisfied by gray hydrogen produced from fossil hydrocarbons such as natural gas – a format that does allow hydrogen to be generated cost-efficiently, but also produces high CO_2 emissions. That is why, to reduce these over the long term, it is becoming increasingly vital to develop industrial plants for producing green hydrogen from renewable energy sources, such as solar or wind energy.

Producing hydrogen in a way that is CO_2-neutral requires the electrochemical process of electrolysis, which involves splitting water into hydrogen and oxygen using electrical energy. The process uses an electrolyzer comprising a cathode and an anode, which are spatially separated from one another by a partially permeable membrane and are brought into contact with water. As soon as electric voltage passes between the cathode and anode, a current starts flowing and the water is split, resulting in oxygen forming at the anode and hydrogen at the cathode. The hydrogen can then be extracted from the electrolysis cell and stored.

Innovative, economical electrolysis solutions are needed to advance the carbon-neutral production of hydrogen so that green methods can be used more frequently to meet the growing demand. Many operating parameters need to be optimized in order to guarantee both a high degree of efficiency and plant safety. PC-based control technology from Beckhoff is ideal for implementing integrated control concepts, as it allows the entire electrolysis process to be automated and monitored. The electrolyzer is controlled locally in the control cabinet via a powerful CX series Embedded PC, which saves space. A control panel can also be used to operate the plant and monitor the plant status in the immediate vicinity. Connected to the embedded PC, EtherCAT Terminals from our extensive I/O portfolio acquire and process safety-relevant data, such as temperature and pressure. Signals are transferred via the real-time EtherCAT fieldbus as standard – and thanks to the openness and flexibility of the Beckhoff system, all other common communication protocols can also be integrated.

Control panels

Control and operation directly in the field – even in hazardous areas

EtherCAT Terminals

Extensive I/O portfolio for capturing almost any signal type

Embedded PCs

Modular and space-saving control system for the DIN rail

All signals integrated in real time: With PC-based control and EtherCAT

Beckhoff uses the principle of PC-based control technology to combine a wide range of I/O components in a single system. For example, EtherCAT Terminals used for integrating functional safety can be freely combined with EtherCAT measurement terminals for precision and high-speed measuring, as well as with I/O modules featuring an integrated safety barrier for connecting intrinsically safe field devices from the hazardous area. These elements can then be integrated into a holistic control system. This means that plant operators in the hydrogen industry have an efficient complete solution at their disposal for all application-related requirements.

With the universal, open EtherCAT high-speed fieldbus that we have developed for PLC, motion, I/O, sensor technology, measurement technology, and safety technology, users also only need a single form of communication technology. With its extended distance technology, EtherCAT also simplifies data acquisition across expansive areas, such as vast energy parks, by allowing communication over distances of up to 300 m. For greater distances, fiber optic solutions with a transmission length of up to 100 km are available. EtherCAT cable redundancy is used to set up a fault-tolerant ring topology to ensure that the network or network segments of a hydrogen plant are always accessible. Moreover, the EtherCAT diagnostic concept enables integrated, complete, and fast error identification. This minimizes downtimes, reduces maintenance requirements, and increases the availability of the plant.

Beckhoff control technology is also flexible and open with regard to integrating third-party EtherCAT devices and other fieldbus systems. Thanks to support for common communication protocols, such as EtherCAT, PROFINET, PROFIBUS, Modbus, or EtherNet/IP, the advantages of PC-based control are also accessible when renewing or expanding existing systems.

The connection can be established via appropriate fieldbus couplers as well as Embedded PCs depending on the application and control topology. This means hydrogen plants are easy to upgrade or optimize, and the system openness protects operators' investments with a view to future expansions.

EtherCAT · PROFINET · Ethernet TCP/IP · IO-Link · PROFIBUS · OPC UA The Industrial Interoperability Standard · CANopen · EtherNet/IP · HART COMMUNICATION PROTOCOL

Fieldbus coupler

Integration of sensors and actuators – via EtherCAT or all other common communication protocols

Safety

Integration of functional safety in the controller with TwinSAFE and safety I/Os

Measurement technology

ELM modules in metal housing for precision and high-speed measurement technology

Explosion protection

Highly compact remote I/O modules with integrated safety barriers for the direct connection of intrinsically safe field devices

PC-based control for safe hydrogen storage and transport

Liquid gas storage tanks and compressed gas storage tanks are the main methods of storing hydrogen. In liquid gas storage tanks, the hydrogen is more compressed and can therefore be stored in a more space-efficient manner and in larger quantities. When it comes to monitoring hydrogen storage tanks, information relating to pressure, temperature, or limit levels is collected directly in the medium. As hydrogen is a highly flammable gas that creates an explosive atmosphere when combined with oxygen, explosion protection requirements need to be taken into account. Signals relating to these can be captured directly from explosion protection zone 0 using the intrinsically safe interfaces of ELX terminals. It is also possible to process signals in accordance with functional safety requirements as needed.

Hydrogen is transported in either a liquid or a gaseous state. Pipelines are the most appropriate form of transportation for the gaseous state, while truck, rail, or ship methods are usually required for liquid gas. In order to monitor pipelines for leaks, the flow, temperature, and pressure of the medium are recorded at regular intervals using ELX terminals and are then transmitted to an edge device via EtherCAT. The edge device – which could be an ultra-compact Industrial PC C6015, for instance – processes the captured signals in order to then transfer them to the cloud. To connect the edge device from remote locations, it is possible to implement both wireless communication via a Beckhoff LTE stick and a wired fiber optic solution via fiber optic cables.

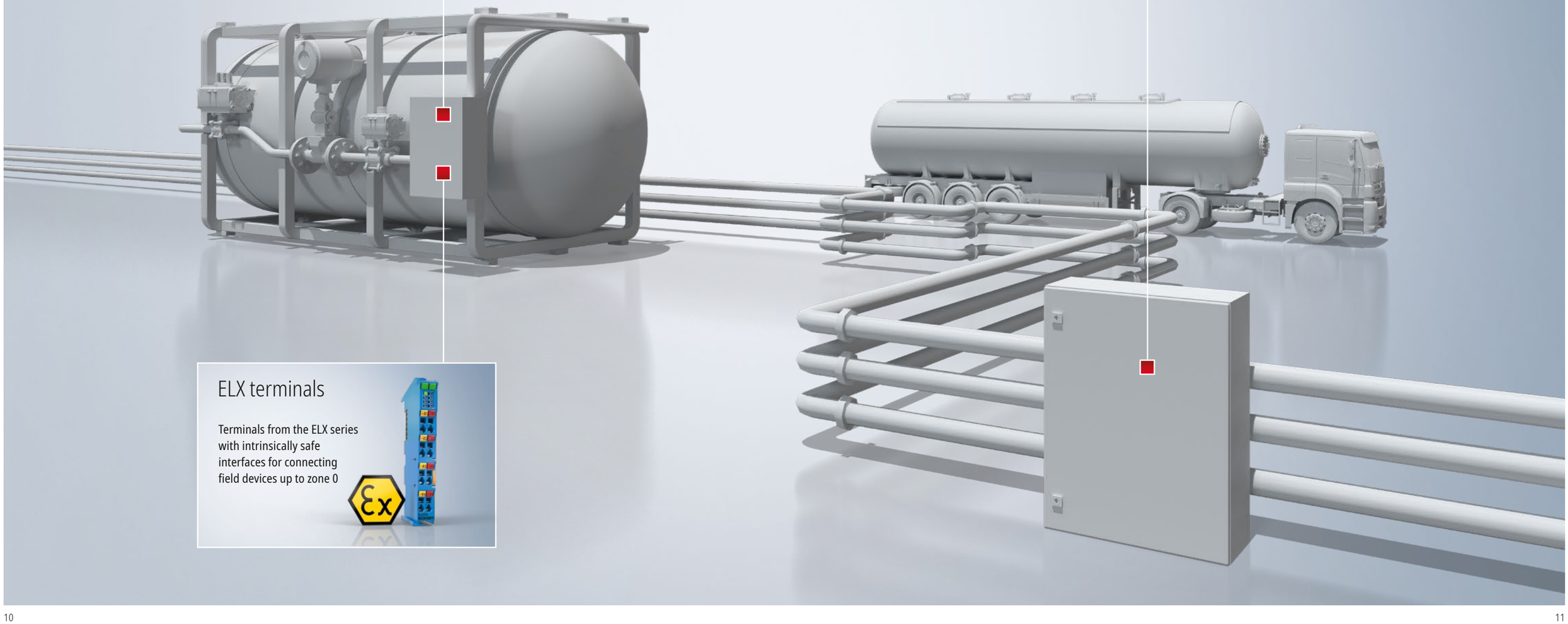
We have a comprehensive portfolio that supports the implementation of holistic solutions for explosion protection up to zone 0: EtherCAT Terminals for intrinsically safe signal capture and functional safety, control panels and panel PCs for plant visualization, plus embedded PCs and bus couplers for easy integration into all common fieldbus systems. TwinCAT also supports the most common telecontrol protocols, for example IEC 60850 and IEC 61870, which are integrated directly into the plant control system using function libraries. In this way, you can implement even complex explosion protection applications in the hydrogen industry with Beckhoff.

Edge device

Controller with integrated cloud connection via series C60xx ultra-compact Industrial PCs

Fiber-optic couplers

EtherCAT infrastructure components with fiber-optic connection enable communication across up to 20 km



ELX terminals

Terminals from the ELX series with intrinsically safe interfaces for connecting field devices up to zone 0

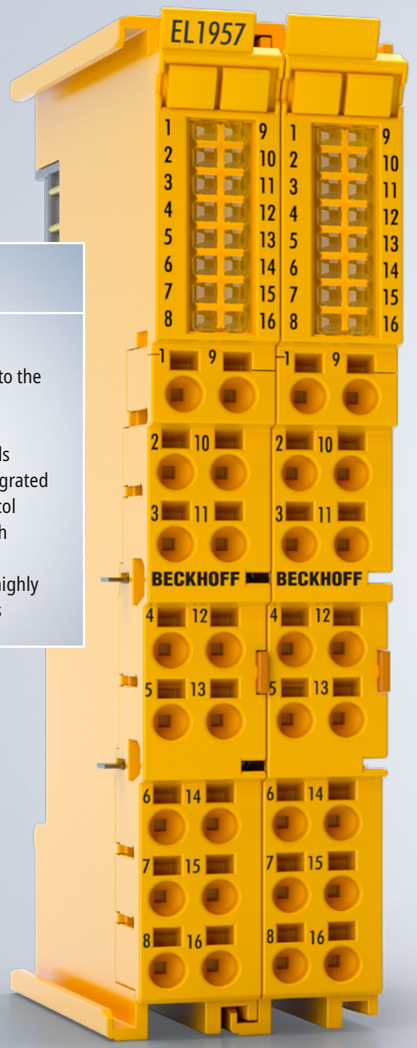
System-integrated: Explosion protection and safety

We meet the growing requirements for process control technology with regard to functional safety by consistently integrating safety technology into the automation system. Thanks to its compact form and modular structure, the TwinSAFE safety solution fits seamlessly into the control platform. Communication via the integrated safety protocol (Safety over EtherCAT) and the modularity of the safety-related controller offer total flexibility when selecting the topology.

The safety I/Os form the interface to the safety-relevant sensor technology and actuators. Due to their integrated logic, complete safety control can be integrated into the EtherCAT system with a single space-saving component.

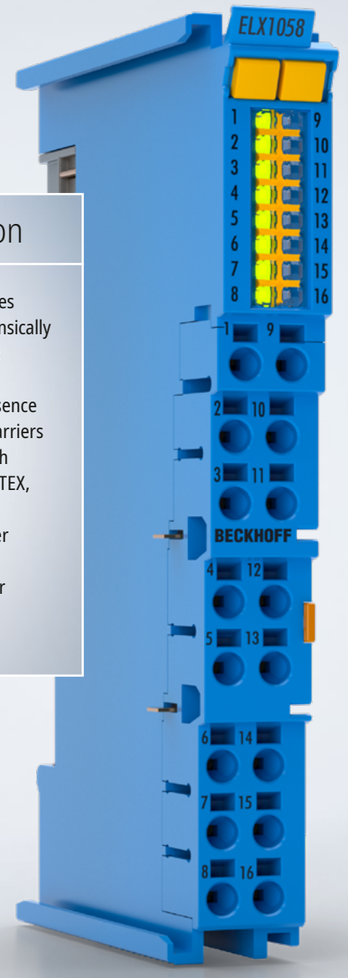
Our ELX terminals combine highly compact remote I/O modules with safety barriers for the direct connection of intrinsically safe field devices. This results in extremely narrow EtherCAT Terminals with intrinsically safe interfaces – and up to eight intrinsically safe inputs are available in the 12 mm housing. The absence of intermediate external barriers leads to a significant reduction in the space needed in the control cabinet and brings cost advantages along with this. With their high resolution and accuracy, the ELX terminals feature the standard of measurement quality that customers have come to expect from Beckhoff. Thanks to certification in accordance with ATEX, IECEx, and NEC/CEC, the ELX terminals meet all industry-specific guidelines for explosion protection and can be used in almost every market worldwide. This allows users to obtain automation components for global use from a single source.

The ELX terminals with integrated safety enable implementation of TwinSAFE safety features up to and including zone 0. This means the extensive Beckhoff I/O portfolio offers a suitable module for every application in the hydrogen industry.



Safety

- seamless integration of the TwinSAFE safety solution into the automation system
- large choice of safety I/Os for all safety-relevant signals
- communication via the integrated Safety over EtherCAT protocol
- complete safety control with a single component
- for small controllers up to highly complex safety applications



Explosion protection

- compact remote I/O modules for direct connection of intrinsically safe field devices from zone 0/20 and 1/21
- space-saving due to the absence of intermediate, external barriers
- can be used worldwide with certification according to ATEX, IECEx, and NEC/CEC
- free combination with other I/O components
- enable holistic solutions for explosion protection up to zone 0/20

Safety and explosion protection

- combination of intrinsically safe interfaces with functional safety
- enables processing of safety-relevant analog signals from zone 0 up to SIL 3

Flexible automation and IoT solutions for hydrogen fueling stations

Using hydrogen may also help the mobility sector do its part in the fight against climate change. Despite decades of development with regard to efficiency and emissions reduction, combustion engines are still one of the biggest sources of greenhouse gas emissions. Electric vehicles and hydrogen-powered fuel cell vehicles are the main potential alternatives.

However, storing electrical energy poses one of the biggest challenges in electromobility. The batteries that are currently used require a lot of space and are heavy, which makes them impractical for many means of transport. The logistics chain is therefore seeking out alternative solutions for powering trucks and for shipping and aviation. Hydrogen has the potential to become the most important energy source in this field in the future. However, refueling with hydrogen is far more complicated than it is with fossil energy sources: hydrogen is compressed at a pressure of up to 1000 bar for the refueling process. In the context of functional safety, it is essential to monitor the pressure while filling and have the ability to shut the process down safely if necessary. What's more, the relevant explosion protection regulations need to be observed as hydrogen is such a flammable substance. Despite these operational challenges, refueling station operators still want to continue providing customers with the kind of easy and convenient refueling experience they are used to.

Efficient automation of processes in hydrogen-based mobility requires a flexible control solution that meets explosion protection and functional safety requirements. With its extensive portfolio of I/O modules and TwinCAT software, PC-based control from Beckhoff forms the basis for implementing custom automation concepts. Integrated TwinSAFE control allows process control to be combined with functional safety in a single system. TwinCAT Analytics provides ready-made libraries and modules for process data processing, meaning captured data such as pressure, flow, and temperature can be analyzed directly in the control software. These values can be used for plant monitoring and visualized via TwinCAT HMI. The results of the analyses can be integrated directly into IoT scenarios via a cloud connection – for example, as a means of checking the plant status via remote access. This facilitates rapid intervention where necessary as well as predictive maintenance, which increases plant availability.

TwinCAT Analytics

Data processing and analysis for condition monitoring concepts

TwinCAT HMI

The Beckhoff Process Library offers a broad selection of controls for the process industry and beyond.

Cloud connectivity

Open communication standards for system-integrated cloud integration via TwinCAT

TwinCAT: The integrated engineering and control platform

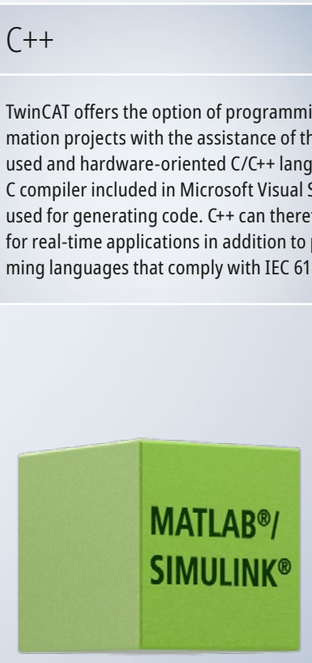
The diverse processes in the hydrogen industry require automation systems to meet different function and performance requirements. The automation software TwinCAT works together with our PC-based control technology to form a scalable automation platform that can be individually adapted to any application.

TwinCAT HMI

TwinCAT HMI integrates the human machine interface directly into the engineering environment of Visual Studio®. The web-based visualization solution enables the convenient development and maintenance of user interfaces for plant monitoring and operation. Visualization can be carried out on any end device regardless of the platform, either directly on the machine or via a web browser for access from any location.

C++

TwinCAT offers the option of programming automation projects with the assistance of the widely used and hardware-oriented C/C++ languages. The C compiler included in Microsoft Visual Studio® is used for generating code. C++ can therefore be used for real-time applications in addition to programming languages that comply with IEC 61131-3.

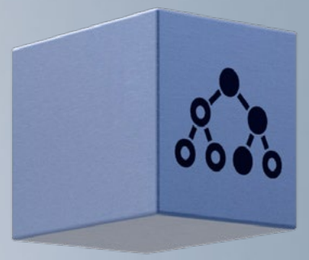


MATLAB®/Simulink®

Thanks to the connection from TwinCAT to MATLAB® and Simulink®, it is possible to integrate models and simulations developed in these languages directly into the controller. Programming that has previously been validated and transferred to the connected TwinCAT system landscape can directly assume the control and monitoring tasks as a productive code – without incurring the risk of unforeseeable errors in the development phase.

TwinCAT Analytics

TwinCAT Analytics enables seamless and cycle-synchronous acquisition of all machine and process data. This data is then used as the basis for extensive analyses that allow predictive maintenance to be implemented. In combination with TwinCAT IoT, even cloud-based big data evaluation concepts can be created, ensuring sustainable quality monitoring for processes.



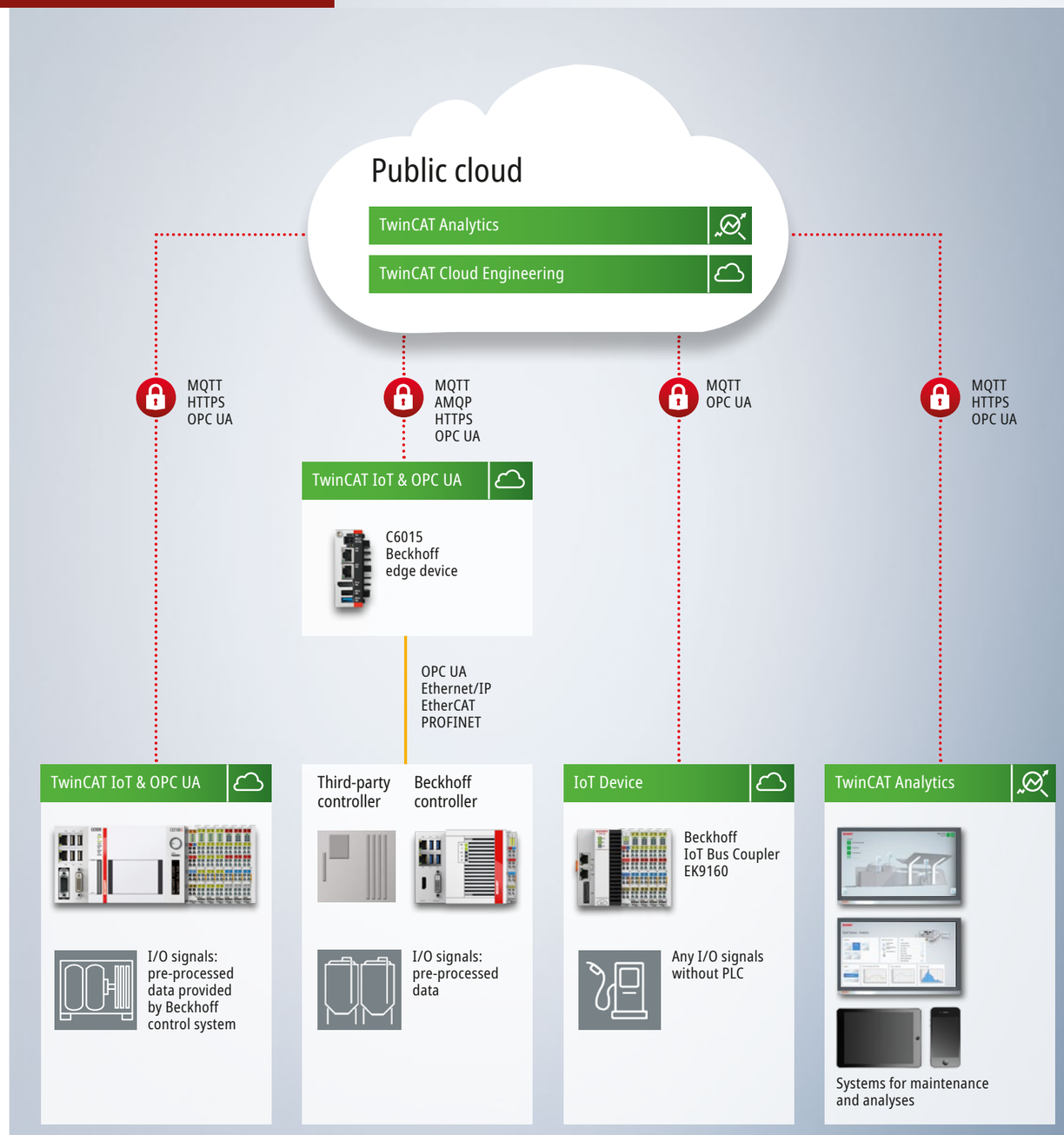
TwinCAT Machine Learning

TwinCAT interfaces to machine learning algorithms allow the use of AI methods in the traditional control environment, supporting product and process optimization. Machine learning models can also be executed in real time using the machine learning solution that is seamlessly integrated into TwinCAT.

Simply and securely into the cloud with Beckhoff

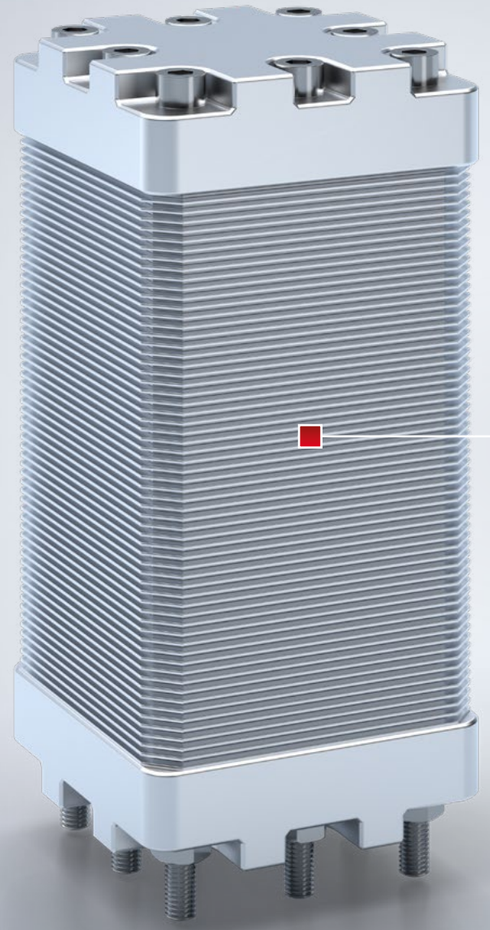
Using cloud-based systems to implement IoT solutions is becoming increasingly popular in almost all areas of automation because IoT scenarios enable more economical process control with consistently high process quality. A classic application is data acquisition in large-scale, widely dispersed plants or remote locations – such as hydrogen pipeline monitoring, for instance. A large area can be monitored and measures can be initiated, if necessary, from a central control room. In addition, the cloud connection makes it possible to operate autonomous systems, such as refueling stations, that can transmit condition or process data via the IoT connection and send messages when errors occur.

Beckhoff's various IoT-enabled components are able to connect to public or private cloud systems for every application scenario. TwinCAT IoT supports the standard MQTT and OPC UA protocols for cloud communication.



Measurement technology for cell-voltage measurement

There is a huge demand for precise measurement technology throughout the entire hydrogen value chain. It is essential to measure the current-voltage characteristic of the individual cells, particularly during the electrolysis process: if the cell voltage is increased, this results in a higher current density and therefore also increased hydrogen production. This is contrasted with reduced efficiency. Accurate monitoring of all parameters makes it possible to select an optimum operating point. However, the installation position of the cells in the stack means that the voltage can only be set for the entire system. Having said that, the individual cell voltages can take on different values and drift over the service life of the electrolyzer. The EL3008-0003 EtherCAT Terminal offers a solution here: The cascaded measuring principle of the terminal significantly reduces wiring work and the high level of insulation allows operation up to a total stack voltage of 1,500 V. This means that the terminal can also be used for large systems. Thanks to the modular concept, the terminal can be used both for test set-ups and for permanent long-term monitoring in combination with the entire plant control system.



The EL3008-0003 EtherCAT Terminal enables the measurement of stacked voltages up to 1,500 V in fuel cells.

Integrated automation: From sensors to the cloud

Big Data Analysis

MQTT
AMQP
OPC UA

MQTT
AMQP
OPC UA

MQTT
AMQP
OPC UA

MQTT
AMQP
OPC UA

Control room

Fuel station

CX2020

DVI/USB, CP-Link 4

Electrolyzer

DVI/USB, CP-Link 4

EtherCAT Extended Distance

PROFINET

EK1101

EtherCAT redundancy

EtherCAT Box

EtherCAT fiber optic

Storage tank

EK1501

Ex ia

Pipeline

EX1100

Ex ib

Ex ia

Our references

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Nel Hydrogen, Denmark

Real-time control
of hydrogen filling stations

▶ **www.nelhydrogen.com**

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GKN Hydrogen, Italy

PC-based control for advanced
hydrogen storage technology

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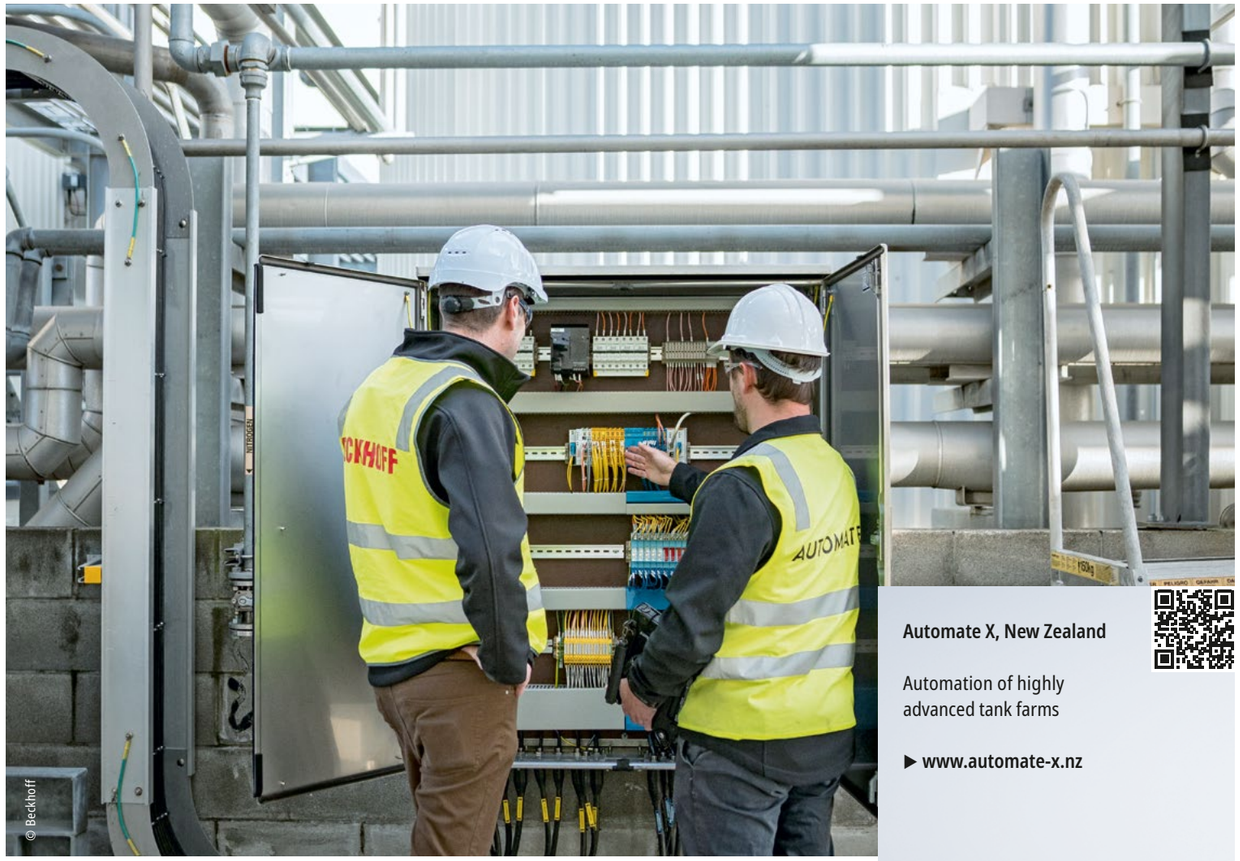

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