MEASUREMENT AND ANALYTICS

Hydrogen custody transfer

The cost of impurities

Hydrogen is an important vector in the energy transition and decarbonization of industrial and chemical processes. The global trade of hydrogen and its derivates such as ammonia will play a key role in the green hydrogen economy.

Introduction

Hydrogen serves, not only, as a crucial raw material for conventional applications, such as crude oil refining and fertilizer production, but is also expected to play an increasingly important role in hard-to-abate sectors, such as shipping and steel generation, and in the generation of synthetic fuels. Nowadays, hydrogen is mainly produced in steam methane reformers (SMR) using fossil fuels such as natural gas or coal (grey hydrogen), which contribute significantly to CO2 emissions worldwide. More sustainable hydrogen production alternatives include the use of Carbon Capture technologies applied to the SMR process (blue hydrogen) and electrolyzers powered from renewable energy sources (green hydrogen). Thus, blue and green hydrogen emerge as effective means for reducing industrial emissions in the long term.

Application

The green hydrogen economy will depend heavily on the global trade of hydrogen and its derivatives, such as ammonia.Green hydrogen production sites will be distributed worldwide depending on the availability of renewable energy sources. Hydrogen also needs to be transported across continents and country borders, stored, and distributed to its final consumers.

For instance, by 2030 Europe expects to cover half of its hydrogen demand with imports, while Germany expects to import up to two thirds of its demand. Such large-scale hydrogen trading scenarios require custody transfer solutions that ensure a reliable, safe and accurate billing of hydrogen across multiple points in the value chain.

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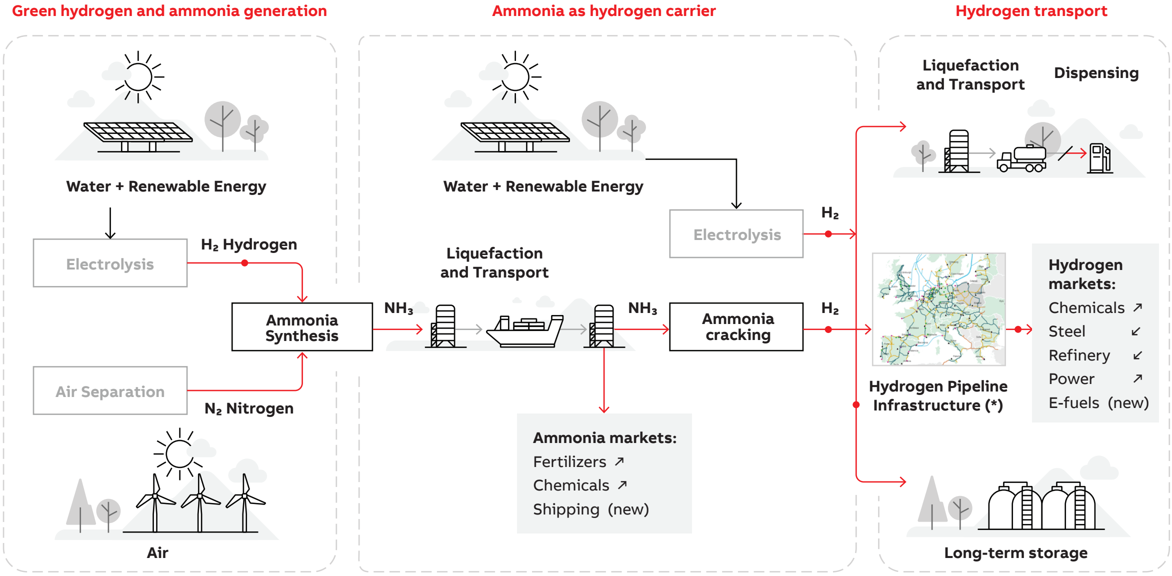
Example of a green hydrogen value chain.

Color coding:
gas, liquid

H2 custody transfer solution



(*) European Hydrogen Backbone Maps | EHB European Hydrogen Backbone

The value chain in Figure 1 shows an example of how the hydrogen economy may evolve and diversify in the coming years. Hydrogen produced in regions with high renewable energy resources may be further transformed into ammonia for overseas transportation.

Further ways to transport hydrogen include liquid organic hydrogen carriers (LOHC) and methanol. Ammonia is the most promising carrier and technologies for its liquification, storage, and transport are already available. After reaching its destination, ammonia may be used directly as feedstock in the existing ammonia market or, to a lesser extent, reconverted into hydrogen via cracking.

Due to the high demand for hydrogen in the industry, most of the available hydrogen, including locally generated hydrogen, will be transported in gas form using re-purposed natural gas pipelines or a new pipeline network to reach its final consumers in the industry. Hydrogen may also be liquefied for local transportation or stored as gas in tanks or caverns for seasonal storage.

Measurement and analytical solutions play an important role across the complete hydrogen value chain for both control and monitoring applications, and in metering for custody transfer and regulatory purposes.

The challenge

Hydrogen custody transfer involves the determination of the net hydrogen quantity at a specific accuracy. A key aspect is to determine the purity of hydrogen being billed. Impurities will always be present and need to be considered for custody transfer. The type and concentration of impurities depend on how hydrogen is generated, stored, and transported. For example, we assume three hydrogen production plants based on electrolyzers with 25, 100, and 500 MW power (Case #1 to #3, respectively). Case #3 represents the scale of the biggest electrolyzer plants currently being built. The components nitrogen, water, and oxygen are typical impurities within the hydrogen gas produced via water electrolysis. The assumed concentrations are within realistic bounds of electrolyzer production.

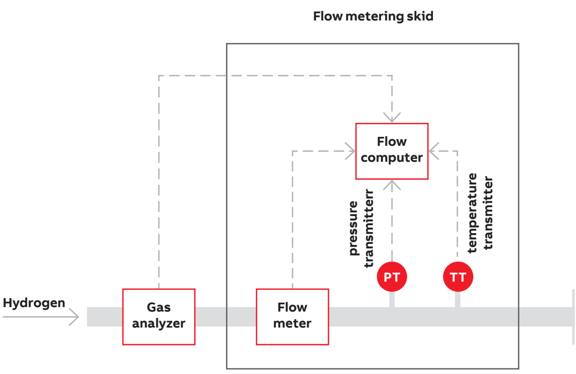
Component	Concentration [mol%]	Mass flow rate Case #1 [kg/h]	Mass flow rate Case #2 [kg/h]	Mass flow rate Case #3 [kg/h]
Hydrogen (H_2)	97,96	441,3	1765,0	8825,2
Nitrogen (N_2)	2,0	126,1	504,5	2522,5
Water (H_2O)	0,02 (200 ppm)	0,8	3,2	16,2
Oxygen (O_2)	0,02 (200 ppm)	1,4	5,8	28,8
Sum	100	569,6	2278,6	11392,8

A mass flow meter will measure the total mass flow of a gas mixture without making distinctions on the individual components. Consequently, the concentration of impurities in the gas mixture, adding up to 2,04 mol%, may cause a measurement error of 22,5% on the mass flow measured. The reason for such deviation is due to the low density of hydrogen compared to all other gases. On a molecular level, the molecular mass of nitrogen (28 g/mol), oxygen (32 g/mol), and water (18 g/mol) are orders of magnitude higher than the molar mass of hydrogen (2 g/mol). Impurities, even in ppm concentration ranges, will cause considerable measurement errors in the net hydrogen mass flow if not considered. Such impurities may add up to considerable monetary losses in the order of tens (Case #1 and #2) to hundreds of thousands (Case #3) of Euros per day! Fiscal metering standards do not allow such deviations to happen in practice and require suitable measurement approaches that can compensate for the presence of impurities.

A simple analogy is as follows: hydrogen custody transfer is like selling feathers by weight and having stones (representing impurities) mixed within the feathers.

The solution

A custody transfer solution is responsible for outputting the net mass flow of hydrogen compensated for pressure, temperature, and impurities present. The required accuracy is specified in international standards such as OIML 140 defining a 1,5% accuracy class. A custody transfer solution is realized by the combination of instruments, analyzers, and flow computers, as shown in Figure 2. It is integrated into a flow metering skid designed for the application needs with an analyzer typically installed upstream of the skid. Similar solutions apply to other gases such as CO_2 in Carbon Capture Utilization and Storage (CCUS) applications. In the case of CCUS, the type and concentration of impurities will differ, but the concept remains the same.



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Gas custody transfer solution with hydrogen as example.

ABB's solution

ABB offers a diverse portfolio of measurement and analytical products to provide a cost-effective custody transfer solution for any accuracy class. All key components can be integrated in collaboration with skid manufacturers. The Return on Investment on an ABB solution pays off in a matter of weeks, or days depending on the application size, compared to the cost of erroneous billing of impurities.

ABB Analyzers are crucial for measuring hydrogen purity. There are several reasons, it can be important for safety (explosion protection), continuity of hydrogen production (health of the stacks at an electrolyzer), or determining the purity of hydrogen for custody transfer.

ABB offers multiple technologies, ranging from gas chromatographs, continuous gas analyzers, tunable diode laser absorption spectrometers, and off-axis integrated cavity output spectrometers.

ABB Analyzers are suited for use in hydrogen applications and can measure impurities such as nitrogen, water, oxygen, methane, carbon dioxide, carbon monoxide, and ammonia content.

Flow-X and TotalFlow flow computers offer seamless integration with all devices, ensuring a good interplay among devices and reducing integration and engineering efforts.

Where applicable, the flow computer calculates the density of the hydrogen mixture with the GERG-2008 Equation-Of-State, corrects the flow meter body for pressure, and temperature effects and applies meter factor linearization to obtain a highly accurate net mass hydrogen quantity.

ABB offers a large variety of flow, temperature, and pressure transmitters for hydrogen applications. Flowmeters such as Coriolis, DP, Vortex, Swirl or thermal meters can measure flow as volumetric, or mass flow value and can cover applications with only a few mbar of pressure to several hundred bars.

The portfolio offers some unique flow technology solutions such as the Swirl meter with high accuracy with minimum installation footprint or the SensyMaster for the lowest pressure and high turn down range measurement even with hydrogen.

All meters offer a large variety of communication protocols and leading solutions for meter verification on-site or remotely. The ABB ability verification suite helps to ensure high reliability and availability in the field.

ABB's pressure and temperature devices offer highest safety as well as highest accuracy with a wide range of different types and technologies. The unique ABB H-shield technology ensures hydrogen suitability of membranes in pressure devices.

The industry's first non-invasive NINVA temperature technology offers excellent accuracy without the need to penetrate process pipes or create safety or measurement accuracy threats.

ABB is validating the existing custody transfer solutions in a metrology Joint Industry Project at DNV and working towards certification according to upcoming MID and OIML 137 & 140 regulations to further ensure the readiness of the ABB portfolio for hydrogen applications.

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AN/HYDROGEN_CUSTODY_TRANSFER-EN Rev. A 06.2024