Technological Challenges for the Green Hydrogen Industry

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This article analyzes the role that green hydrogen maintains in the current industrial sector. In addition to analyzing the characteristics of this clean fuel, and answering the questions that arise in the face of what has come to be called the "hydrogen boom", the author dwells on the technological challenges involved in its implementation and the answers that are offering the industry for the equipment of a green hydrogen plant.

KEYWORDS: Green hydrogen, Renewable energies, Industrial plants, Equipment, Sustainability.

En el presente artículo se analiza el papel que el hidrógeno verde mantiene en el sector industrial actual. Además de analizar las características de este combustible limpio, y dar respuesta a los interrogantes que se producen ante lo que se ha venido en llamar "boom del hidrógeno", el autor se detiene en los retos tecnológicos que supone su implantación y las respuestas que está ofreciendo la industria para el equipamiento de una planta de hidrógeno verde.

PALABRAS CLAVE: Hidrógeno verde, Energías renovables, Plantas industriales, Equipamiento, Sostenibilidad.

WHY RIGHT NOW?

Hydrogen is the simplest element, made up of a proton and an electron, and the most abundant in the Universe. Its characteristics include that it is the only fuel that does not produce CO_2. Its combination with O_2 simply produces water.

In addition, it can be transported and stored (as pressurized gas or as liquid). This is precisely what makes it an energy vector (a substance that allows energy to be stored and released in a controlled way and on demand).

The use of hydrogen is not new, it has been with us for many years (the first prototypes are from the early 90s) and many companies have dedicated years and large investments to its research.

With all this, it is worth asking, why now? Why this great interest in the production of green hydrogen? The answer to this question is not easy, since there are many factors are involved in its answer. In any case, there are three points that have had a notable influence so that we are currently experiencing the "hydrogen boom":

- **Fight against climate change**

There is no doubt that the global average temperature has risen, and in recent years considerably and alarmingly. Much of the cause is the emission of CO_2 into the atmosphere, mainly from industry and the consumption of fossil fuels.

The 2005 Kyoto protocol and the extension of its terms in the 2015 Paris Agreement can be considered as the starting points for the hydrogen boom, as this is considered one of the main ways to reduce CO_2.

- **Investments**

As a result of the above, the participation of public and private entities is being promoted at all levels, as well as the economic investments necessary for the development of the necessary technologies and the execution of projects, and the optimization of the entire value cycle with in order to reduce CAPEX (it must be taken into account, as a reference, that currently the production of gray / blue hydrogen has a cost of 1.6 - 0.6 € / kg compared to 7.0 or 5.0 €/ kg of green hydrogen).

We are at a time when we can talk about more than 200 projects presented worldwide (about 130 in Europe) in different stages of development.

- **Technological advances**

Although it may seem like something very new, actually a large part of the technology necessary for the production of green hydrogen has been among others for years and production costs are being significantly reduced.

The problem is given because almost all this technology has to be adapted to the requirements of hydrogen.

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TECHNOLOGICAL CHALLENGES

If we look at its main physico-chemical characteristics, we can realize that we are talking about a very special gas:

FIGURE 1.

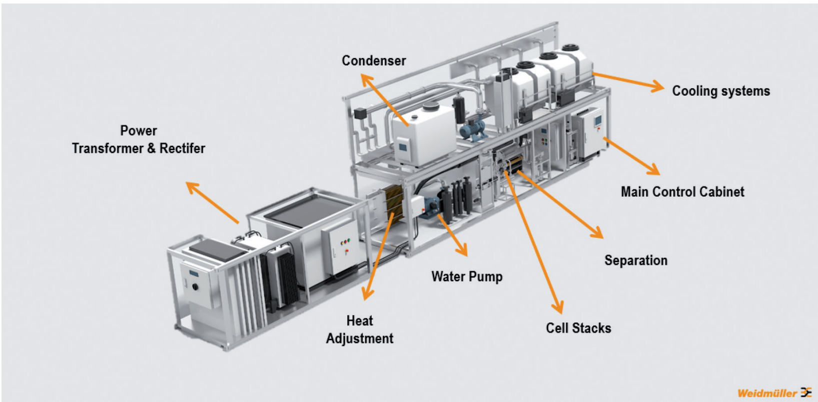
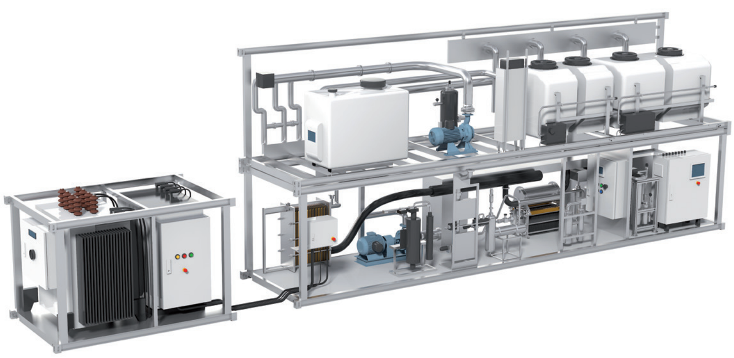


PHOTO 1



• Hydrogen has a density 6 to 10 times lower than natural gas (mainly methane). Among other houses, the final elements must be adapted.

• It has a high energy density in mass: 120MJ / Kg (2 times that of natural gas).

• It has a low energy density in volume: 10.8MJ / Nm3 (1/3 of that of natural gas). These two parameters mean that a lot of volume is needed to produce the same energy as Natural Gas.

• It has a very low boiling point: -253 °C. This causes complex transport.

• Wobbe index similar to that of natural gas (11.29KWh / Nm3, that is, 5/6 of NG).

• Highly flammable. This forces to take into account areas with risk of explosion and all its regulations.

• It is a renewable energy vector that is not in a free state. You have to "make it".

These characteristics are what make existing technologies have to be adapted. For example, the Natural Gas distribution network is prepared to transport methane, but not hydrogen. For this reason, currently only one injection of only 5 % is allowed (10 in some countries)

Another example to take into account is the conversion of a machine for use in non-classified areas to classified areas. Indeed, we are talking about a highly flammable gas (in fact, in the ATEX / IECEx classifications it is considered the most restrictive).

This means that the design of a machine (compressor, electrolyzer, etc., Figure 1 and Photo 1), has to take into account all the design criteria for areas with risk of explosion. Thus, for example, the control cabinet (which, regardless of its functionality, previously only took into account factors such as the IP protection degree or the K impact protection) will have to be in an enclosure that complies with everything indicated in the normative.

The explosion zone in which it will be immersed must be taken into account (from greater to lesser possibility of the presence of explosive gas: Zone 0, with greater, Zone 1 or Zone 2). Depending on this and various factors (such as ambient temperature), the cabinet's protection mode can be defined (Intrinsic Safety, Increased, Anti-deflagrant, Pressurized, etc.). Each of them must take into consideration their particular design criteria (conductor cross-sections, components, cable inlets / outlets, internal distances, etc.).

In Figure 2 you can see an example of how one of these cabinets is designed. It is a control panel that includes two power supplies (in redundancy), and an automaton and its I / O cards, as well as auxiliary elements such as terminals and breackers circuits. By modeling the thermal dissipation of the elements in different load situations, the resulting surface temperature is calculated, a very important point to ensure that it is always below the ignition temperature of the explosive gas. This study includes the optimal configuration of the elements so that the internal air flow is optimal. As we can see, we are talking about a "standard" control cabinet but adapted to the new environment.

FIGURE 2.

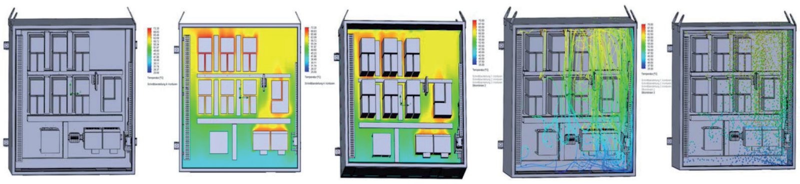


FIGURE 3.

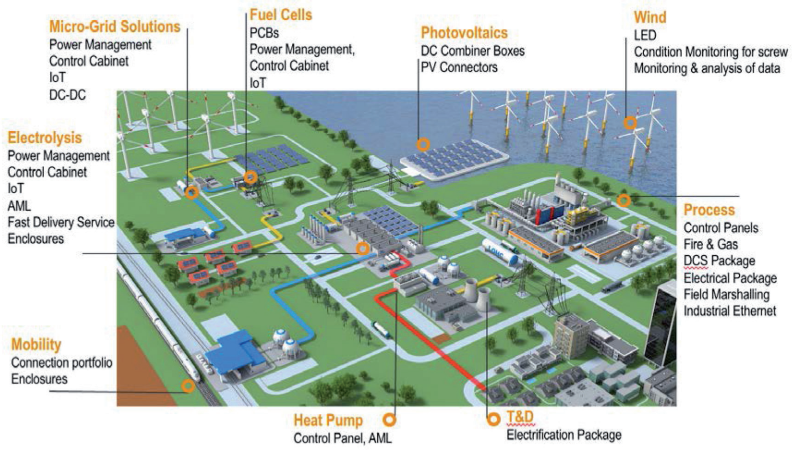
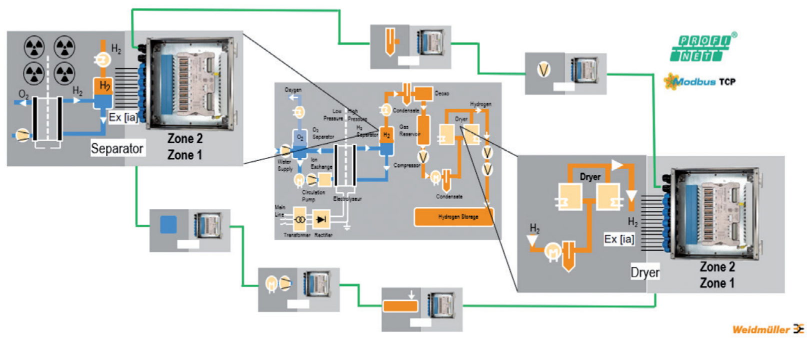


FIGURE 4.



It is highly recommended to contact recognized companies with experience in the design of ATEX/IECEx boxes to advise on the design of this type of enclosure.

Another technological challenge has to do with the integration of industrial segments that have so far operated "independently", each one with its peculiarities and "hobbies" (for example, the use of communication buses of different types). In Figure 3 we can see what a typical green hydrogen production plant could be. As we know, the "color" is given by the origin of the energy and the process selected for the creation of hydrogen and its corresponding net emission of CO_2. In the case of green, we are talking about renewable sources and a circular economy.

In order to reduce CAPEX and optimize these types of plants, it is increasingly necessary to:

- **Modularization**

Use of integrated, free and independent design tools (such as Weidmuller Configurator, Eplan, Ecad and others), easy-to-install infrastructures, as well as that provide the possibility of plug & play connection for both energy transport, as well as signals and data.

This makes it possible to base ourselves on basic designs that are easily adaptable to various types of installations.

- **Standardization**

Thanks to the use of modular and flexible solutions, they can be standardized in the designs of the plants, with the consequent reduction in costs, both of the necessary goods, as well as their operation and maintenance.

In Figure 4 we can see a possible example of a modular solution for connection of input / output signals in the field that allow the use of several field buses (flexibility), adaptability to the needs of the installation (modularity), and its possible employment in other facilities with other requirements (standardization).

- **Automation and Digitization (IoT)**

The famous digitization that you hear so much about, takes its maximum value here. Remote accesses (with reduction of services "in situ"), Process Control and its visualization, Control of energy consumption and predictive maintenance are totally necessary.

In conclusion, we are experiencing a time of change in which points that until now had been addressed independently and very focused that are a great challenge for the industry and from which we are all immersed in a learning process converge in a single model collaborative with a purpose as important as it is to look for a better world.