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Preliminary study for the adequacy and implementation of a hydrogen laboratory

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A B S T R A C T

Hydrogen, within the so called Hydrogen Economy, has the potential to become the energy carrier of the future which could change entirely the energy industry. It could help to change to a more reliable, efficient and environmentally friendly energy sector.

Hydrogen Economy is based on different technologies which are related to the scientific and industrial sectors. Thus, all equipment included within hydrogen technologies are in an experimental stage or in a too early market, safety being one of the research lines followed in the design and use of these equipment and devices. This paper includes the design and implementation of different building works to have a place to operate in a safe way electrolyzers and fuel cell systems that belong to a research project in which *Centro Nacional del Hidrógeno* (CNH2) is taking part in its current facilities.

Because of working with hydrogen, the whole design was considered from the point of view of the potential to generate explosive atmospheres.

1. Introduction

It is expected that world's energy demand will be increasing continuously, being more intense in today's developing countries [1]. Nowadays, hydrogen is considered as the element which can assume the role played during the last century by fossil fuels. Hydrogen is a potentially clean energy carrier with a low environmental impact, because it can be produced from water, broken down by inputting energy, either from renewable sources or possibly from biomass.

The generation, storage and transformation of hydrogen into energy are known as hydrogen technologies. Efficiency and environmental reasons and the fossil fuel dependence make possible the way towards the Hydrogen Economy [2], even though the particular physical and chemical properties of hydrogen make it challenging to store, transport and manipulate.

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In the previous context is developed the purpose of *Centro Nacional del Hidrógeno (CNH2)*, located in Puertollano (Ciudad Real), which main aim is scientific and technologic research about all aspects related to hydrogen technologies, being at scientific and technologic national and international service.

This paper covers the conceptual design and requirements to build an enclosure where electrolyzers, storage and fuel cell systems can be operated safely, within the *GEBE project* (*Gestor de Balances de Redes Energéticas con Generación Distribuida Inteligente*), a project in which CNH2 is working nowadays.

2. Hydrogen safety and regulations

First, an overview of the key European safety legislation that applies to hydrogen is described. EU Directives 1994/9/EC and 1999/92/EC, commonly referred to as the ATEX Product and User Directives respectively, are the main regulations which have to be followed when the needs of a place, that works with hydrogen, want to be known:

- Directive 94/9/EC, of 23 March 1994, on equipment and protective systems intended for use in potentially explosive atmospheres (ATEX)
- Directive 99/92/EC, of 16 December 1999, on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres

There are other directives that have been used in this work but these ones are common for several installations.

- Directive 97/23/EC, of 29 May 1997, on the approximation of the laws Members States concerning pressure equipment
- Directive 2002/91/EC, of 16 December 2002, on the energy performance of buildings
- Directive 2006/05/EC, of 12 December 2006, on the harmonization of the laws of Member States relating to electrical equipment designed for use within certain voltage limit. In this case, the most important issue that has been checked is related with electrical installations in potential explosive atmospheres.

However, each EU Member States is required to transpose any Directive and to implement its provisions, as a minimum, through their own domestic legislation [3]. In Spain, the documents which transpose the previous directives are named *RD 400/1996*, *RD 681/2003* for ATEX directives respectively, and *RD 2060/2008*, *RD 1027/2007* and *RD 842/2002* for the other ones.

More regulations have been used but these ones have been developed by the Spanish administration and are related with chemical products storage, for example.

To study all aspects of hydrogen safety, standards have to be taken into account too because they can be helpful to designers and engineers. As a reminder, standards are usually published either by organizations associated with the promulgation of international standards. In the case of Spain, this organization is *AENOR* and its standards are named *UNE*. So, the standards which have been followed for this study are the adaptations/translations of standards from *International Electrotechnical Commission (IEC)*:

- IEC 60079-10-1 "Explosive atmospheres - Part 10-1: Classification of areas. Explosives gas atmospheres"
- IEC 60079-14 "Explosive atmospheres – Part 14: Electrical installations, design, selection and erection"

3. Installations systems description

3.1. *Systems equipment installations*

The present paper describes the different tasks which have been carried out in one of the laboratories of CNH2, which is next to a gas storage room, in order to fit them out for hydrogen use. The main purpose is to present considerations and adopted solutions in order to have a safe installation to operate equipment which generate storage or transform hydrogen. In general, and according to Regulations, Codes and Standards (RCS) from previous section, places where hydrogen is present are classified as hazardous areas because of an explosive atmosphere (ATEX) is or could be present, so special considerations must be taken to build, install and operate in these kinds of emplacements [3,4]. Design is only one of the components of Safety, which is completed with operatives and organizational aspects related with risks analysis [8].

In order to achieve the different aims of GEBE Project two different smartgrids were configured. Each one of these smartgrids uses hydrogen as energy carrier and photovoltaic and minieolic technologies as energy sources. General specifications of the equipment which compound both smartgrids are summarized next:

Smartgrid 1: PEM (Polymer Electrolyte Membrane) electrolyzer 1 kW, chemical storage system in metal hydrides (1.5 Nm^3 $H_2 \times 2$) and a PEM Fuel Cell system 1 kW. The highest pressure which can be reached by the system is $15 \cdot 10^5$ Pa.

Smartgrid 2: Alkaline electrolyzer 5 kW, booster to increase hydrogen pressure (compression ratio ≈ 1/10), storage system compounded by 3 gas cylinders at $20 \cdot 10^6$ Pa (8 Nm^3 $H_2 \times 3$) and a PEM Fuel Cell system 4.5 kW. The highest pressure which can be reached by the system is $20 \cdot 10^6$ Pa.

Both smartgrids have a similar operating mode. An electrolyzer is powered by electricity from a renewable source with the aim of producing hydrogen. This hydrogen is stored in order to transform it into electricity again by means of a fuel cell. Fig. 1 shows the operation scheme.

3.2. *Initial conditions*

Fig. 2 shows how the laboratory was when it was decided to develop the GEBE Project inside it. The gas storage room was in similar conditions.

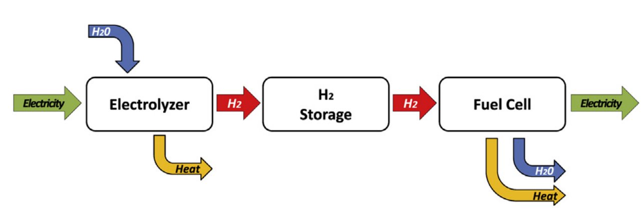

Fig. 1 – Operation scheme for smartgrids from GEBE project.