GreenH2CM. Fuel cell-based hybrid powertrain research and testing laboratory for maritime and aeronautical environments

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Abstract:

Power trains based on fuel cells hybridized with any secondary power sources provide similar effectiveness levels than current powertrains based on internal combustion engines but achieve better efficiency values and have the potential to be free of harmful emissions. However, the development of these powertrains is still in its childhood and research efforts must be reinforced, especially in marine and aeronautical applications. One part of the project GreenH2CM will provide a valuate tool that will support the research in this area. In the frame of the GreenH2CM Activity Line "Uses of hydrogen in heavy transport, aviation and maritime sectors", the research group PiCoHiMA from the Universidad Politécnica de Madrid (Spain) is developing a Laboratory for testing fuel cell integrations for marine and aeronautical applications. The resulting installation will allow to test fuel cell stacks with powers up to 300 kW and the simulation of hybridized secondary power sources as batteries or capacitors. The laboratory will not only allow to monitor and control the critical parameters of the stack under study to simulate adequate environmental conditions, besides, a 6-freedom degrees hexapod will allow to simulate the movements of the platform to study its impact.

Keywords:

Hydrogen; PEM fuel cell; propulsion; test bench; marine; aeronautical.

1. Introduction

Although green hydrogen is a versatile energy carrier that will play a key role in meeting the decarbonisation targets to which Spain has committed, a major R&D&I effort is still needed for it to be considered as an economically viable alternative.

The project that is presented here, "Strategic Positioning of the Community of Madrid in Green Hydrogen and Fuel Cell R&D&I GreenH2CM", is being developed by several national and regional research institutions and is funded by the Ministerio de Ciencia e Innovación de España (Spanish Ministry of Science and Innovation) MCIN/AEI/10.13039/501100011033, by "NextGeneration EU/PRTR", and by the Regional Government of Madrid, in the frame of the Complementary Plans. GreenH2CM project pursues three general objectives in the field of Hydrogen and Fuel Cells:

- To structure and coordinate the R&D&I capacities of the Madrid Region, among themselves and with other Spanish Regions with common interests, around the green hydrogen value chain and its application by means of: (i) optimisation of the connection between renewable electricity generators and electrolysers, (ii) innovative high temperature hydrogen production techniques with reversible operation capability, (iii) optimisation of fuel cell integration and (iv) safe combustion techniques of hydrogen and its mixtures for use in the industrial, residential and transport sectors. These innovative concepts will allow the necessary progress in reducing the production costs of green hydrogen so that it can reach the market.
- To collaborate in defining the Madrid Region strategic lines of work on new concepts of green hydrogen production and fuel cell applications that generate industrial and economic value and act as an instrument to position the Madrid Region at national and European level in the development of these technologies. It also aims to establish alliances and cooperation agreements on renewable energies,

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green hydrogen and fuel cells and to promote technological surveillance and competitive intelligence to identify new work niches in this area.

- To educate and train researchers, through the recruitment of research personnel at different stages of their training, and to generate human capacities for the development of a national industry covering the entire value chain around green hydrogen and fuel cells.

Therefore, this R&D will complement and help support national industry in the development of innovative electrolyser concepts with higher efficiency, longer life and lower cost, as well as other hydrogen generating systems from concentrated solar energy; integration of fuel cells in transport (air, maritime, rail and road), industry and building applications and the development of new combustion devices and/or the adaptation of existing ones to move towards decarbonisation and climate neutrality.

The GreenH2CM Project addresses the development of five main lines of action (LIA), out of the 13 lines included in the Green Energy and Hydrogen programme of Complementary Plans:

- LIA1: Low temperature green hydrogen generation from renewable energy.
- LIA3: High-temperature hydrogen generation from renewable energy and waste heat utilisation.
- LIA7: Uses of hydrogen in heavy transport, aviation and maritime sectors.
- LIA8: Uses of hydrogen in the industrial combustion sector.
- LIA11: Techno-economic studies and market launch of utility models. Dissemination, education and training activities for new researchers.

2. Uses of hydrogen in heavy transport, aviation and maritime sectors (LIA7) in GreenH2CM

Since the beginning, mankind has need for mobility. Means of transport have evolved looking for higher speed, safety, and more power and efficiency. This evolution has been always supported by scientific and technical developments allowing the transition from human or animal power to steam, from steam to oil and, more recently, from oil to electrochemical energy stored in batteries and alternative fuels to look for more environmentally friendly solutions. In this sense, hydrogen and fuel cells are a promising technology for the mobility of the future that should make it possible to decarbonise those transport segments in which electrification does not provide a competitive solution compared to conventional combustion technologies. The aim of LIA7 is to investigate and develop advanced technological solutions for the integration and optimal operation of hydrogen-based systems for heavy, air and maritime transport applications.

The overall objective of Line of Action 7 (LIA7), *Uses of hydrogen in heavy transport, aviation and maritime sectors*, of the GreenH2CM project is to:

- Design, build and operate a facility for the testing of fuel cell integrated power trains in the maritime and aviation sectors.

In general terms, this line of action includes: a) Development of technology to improve the reliability of the energy and degradation models of fuel cells to optimise their subsequent sizing and operation in hydrogen-based vehicles. b) Development of advanced methodologies to optimise the sizing of hybrid traction solutions (fuel cells with batteries) and their configuration and thermal management. c) Generation of innovative solutions for the intelligent management of hydrogen-based vehicles, ships and aircraft to optimise their operation throughout their useful life.

The *expected results* are summarized as follows:

- Training to develop detailed dynamic models of the tested power generation system and its components for real-time simulation and/or digital twin applications;
- Implementation of a power distribution system that will connect the primary and secondary sources (fuel cell, battery and supercapacitor) to the load, which will reproduce the power operating profile under test;
- Development and qualification of the heat exchangers necessary to perform proper thermal management of a fuel cell-based power generation system on board a commercial aircraft;
- Prototype demonstrator of a hydrogen fuel cell hybrid vehicle, operational and functional in the field of heavy road, port and/or airport transport;
- Fuel cell testing capability with impurity measurements in the gas streams under various operating conditions.

The main work involved in this LIA7 of GreenH2CM is the development of a laboratory for the testing of powertrains in the maritime and aviation sectors. It is described in Section 3.

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3. Laboratory for testing fuel cell integrations for marine and aeronautical applications

In order to be able to carry out research, training and provide services to private companies, it is necessary to develop the design, construction and commissioning of a facility to test fuel cell integration in power trains for marine and aeronautical applications. Figure 1 shows the preliminary design of the facility.

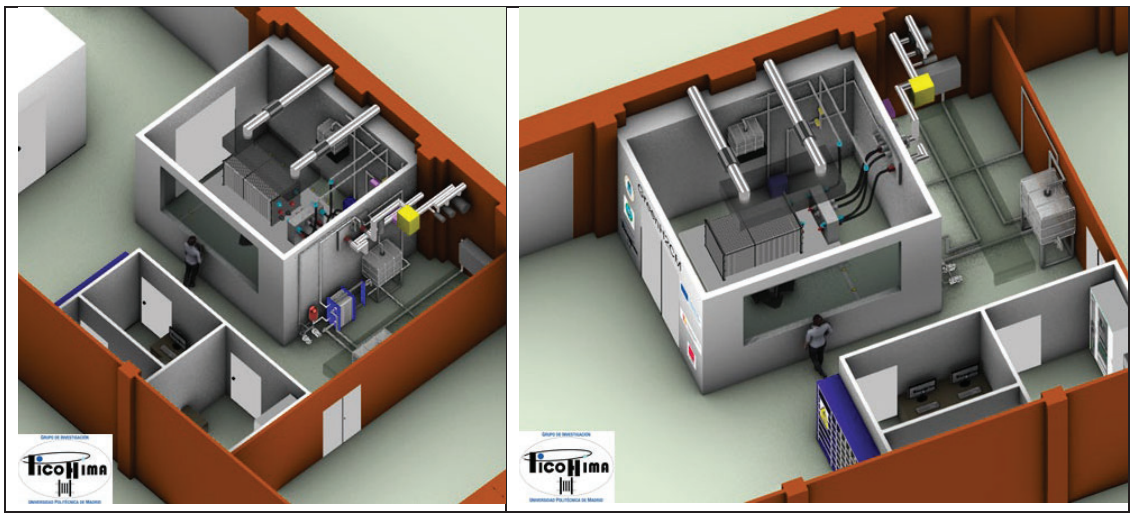

Figure 1. Two views of the preliminary design of the Laboratory for testing fuel cell integrations for marine and aeronautical applications in the frame of the GreenH2CM project.

The tasks planned to achieve this facility are as follows:

- Detailed design of the test facility.
- Selection of components and services for the test facility.
- Procurement of components and services for the test facility.
- Construction of the test facility.
- Configuration, testing and commissioning of test facility systems.
- Operational tests with real operating profiles of a fuel cell and battery integration, with and without movements.

In addition to this, it is planned to develop: a Doctoral thesis on the subject, dissemination activities and establish company-university agreements.

The resulting installation will allow to test fuel cell stacks with powers up to 300 kW and the simulation of hybridized secondary power sources as batteries or capacitors. The laboratory will not only allow to monitor and control the critical parameters of the stack under study to simulate adequate environmental conditions, but a 6-freedom degrees hexapod will allow to simulate the movements of the platform to study its impact.

This facility will be located at the Escuela Técnica Superior de Ingenieros Navales (Technical School of Naval Architects and Marine Engineers) of the Universidad Politécnica de Madrid (Spain) and will be under the management of the PiCoHiMA Research Group [1]. This Laboratory is an important asset that will offer valuable services to both the academy and the private sector. This facility can be integrated into large projects, allowing fuel cell solutions to be tested not only at a laboratory scale but also at a near-market scale, ensuring the quality of the final product at a critical stage of its development where such tools are scarce. This is an advantage for companies and research institutions in ensuring the reliability of their developments.

4. Conclusions

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GreenH2CM is an important project that poses the basis for the development of critical knowledge and facilities around hydrogen technologies in the Madrid Region also structuring and coordinating the R&D&I capabilities in this Region.

Among the five Lines of Action covered by this project, the Line of Action 7 “Uses of hydrogen in heavy transport, aviation and maritime sectors” stands out.

The purpose of this Action Line to research and develop advanced technological solutions for the integration of hydrogen-based systems for heavy transport, aviation and maritime applications is reflected in its main objective, i.e. the design, construction and operation of a facility for the testing of fuel cell integrated power trains in the maritime and aeronautical sectors.

The resulting installation will allow to test fuel cell stacks with powers up to 300 kW and the simulation of hybridized secondary power sources such as batteries or capacitors, including the impact on the fuel cell stack of the movements induced by a 6-freedom degrees hexapod that simulates the movements of the platform where the stack is embarked.

This laboratory is an important asset that will provide valuable services to both academia and the private sector, facilitating the testing of fuel cell systems not only at laboratory scale but also at near market scale, ensuring the quality of the final product at a critical stage.

Acknowledgments

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[1] (https://blogs.upm.es/picohima/).