The EU Project FCH2RAIL - Fuel Cell Hybrid PowerPack for Rail Applications

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Abstract

The project FCH2RAIL aims to combine the advantages of electric traction with overhead catenary and fuel cell hybrid powertrain for non-electrified track in a Bi-mode multiple unit. The intention is to replace the polluting diesel powertrain currently used on non-electrified tracks by a Fuel Cell Hybrid PowerPack (FCHPP). This FCHPP is consisting of fuel cells and batteries; it will reduce emissions significantly and still have a highly-efficient catenary-electric powertrain in the same multiple unit. The main tasks and results of FCH2RAIL project are:

1. to develop, build, test and homologate a Fuel Cell Hybrid PowerPack (FCHPP). This scalable, modular and multi-purpose energy source shall be applicable for new vehicles in different rail applications (Multiple Unit, Mainline and Shunting Loco) and also suitable for retrofitting existing trains.
2. to demonstrate FCHPP in a Bi-mode Civia commuter multiple unit. This demonstrator will use external energy supply in catenary operation and the fuel cell hybrid system on non-electrified sections.
3. to identify and benchmark innovative solutions to improve energy efficiency in fuel cell trains. The competitiveness of fuel cell traction against existing diesel solutions shall be demonstrated, and the energy saving potentials of innovative HVAC systems will be analysed.
4. to propose a normative framework for hydrogen in railway vehicles, to identify Gaps in existing hydrogen and railway standards and to contribute to existing standardisation activities.

Keywords: fuel cell; hydrogen; bi-mode; demonstrator

1. Introduction

Half of the railway lines in the European Union are electrified and already enable local emission-free rail transport. Diesel-powered trains are used on the remaining sections of the lines, but today's diesel trains have restrictions in speed and acceleration compared to vehicles powered from overhead lines. Although more and more of these railway lines are being electrified across Europe, this is a very expensive and long-term venture that always depends on the local geographical conditions.

In the EU project FCH2RAIL (Fuel Cell Hybrid Power Pack for Rail Applications), the consortium is developing and testing a new type of train prototype with partners from Belgium, Germany, Spain and Portugal: At the heart of the project is a hybrid, bi-modal drive system that combines the electrical power supply from the overhead line with a hybrid power pack consisting of fuel cells and batteries that is independent of the overhead line. The basic idea: Where energy is available from overhead lines, the train continues to run on it. Where there are no overhead lines, the energy comes from the fuel cell battery system, the so called Fuel Cell Hybrid Power Pack FCHPP. In the project it shall be demonstrated that this type of bi-mode power pack is a competitive and environmentally friendly alternative to diesel power that combines the advantages of high performance and acceleration under overhead catenary with the autonomy of diesel-powered trains.

With a budget of 14 million euros, the eight partners (Figure 1) of FCH2RAIL project aim to develop, demonstrate

and approve such a system until December 2024. The project is funded with 10 million euros by the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) under grant agreement No. 101006633 [1].

Figure 1: Partners of the FCH2RAIL project

2. FCH2RAIL objectives

The main objective of the FCH2RAIL project is to develop, build, test, demonstrate and homologate a scalable, modular and multi-purpose Fuel Cell Hybrid PowerPack (FCHPP) applicable for different rail applications (multiple unit, mainline and shunting locomotives) also suitable to retrofit existing electric and diesel trains, to reach TRL7. The project starts with a multi-country, multi railway-use-case analysis in order to derive requirements for the design, implementation and test of the FCHPP.

Based on that the FCHPP will be designed and demonstrated in a retrofitted Bi-mode multiple unit that draws electricity from the catenary while operating on electrified sections and uses the FCH system as power source on non-electrified sections supported by an innovative train wide energy management system to minimise the energy and power consumption. In order to improve the energy efficiency of FCH traction systems, innovative on-board solutions for HVAC are identified and benchmarked. The train demonstrator tests will be carried out cross-border in Portugal and Spain and homologation will be seeked for three EU countries.

A systematic screening of H2 and rail related EU-wide normative and standard frameworks concerning gaps related to an EU-wide implementation of FCH Bi-mode trains will be carried out. These activities, closely interconnected to the design, testing and homologation of the FCHPP demonstrator train activities, will result in the proposition of changes to and active involvement in standardization and norming workgroups.

An important aim of the FCH2RAIL project is to demonstrate the competitiveness of FCH against diesel trains. Therefore, project related KPI are collected and implemented to a LCC model which is applied to different rail sectors deriving cost reduction potentials. Last but not least dissemination will comprise the demonstration of the FCHPP and the train demonstrator complemented by intensive communication and publication activities.

3. The FCHPP Concept

The innovative Fuel Cell Hybrid PowerPack (FCHPP) concept starts with the ambition to be suitable for newly developed rolling stock as well as for retrofitting of existing electric and diesel trains. It is a modular and scalable power source applicable to multiple units, mainline and shunting locomotives, and it can also be used in Bi-mode traction systems in combination with overhead catenary. The holistic energy management developed in FCH2RAIL enables adaption to the application specific requirements in terms of power, range on non-electrified sections, autonomy; furthermore, it manages energy efficient operation, thus reducing hydrogen consumption and eventually operating cost of the autonomous fuel cell hybrid trains.

The FCHPP concept (Figure 2 right) covers all onboard energy sources of a train. It includes the fuel cell system modules and cooling system, the batteries and battery thermal management system (BTMS), hydrogen storage and interface to hydrogen refueling station (HRS), the power electronics such as DC/DC converters and last but not least the energy and thermal management. The energy supply system is to be designed in such a way that

power and range can be expanded based on a modular principle: The number of fuel cell and battery modules influences the drive power; the number of hydrogen tanks determines the range on non-electrified lines. This way, the drive unit can be designed for use in both passenger and freight transport. This design also makes it possible to produce the required components in greater numbers and thus more cost-effectively.

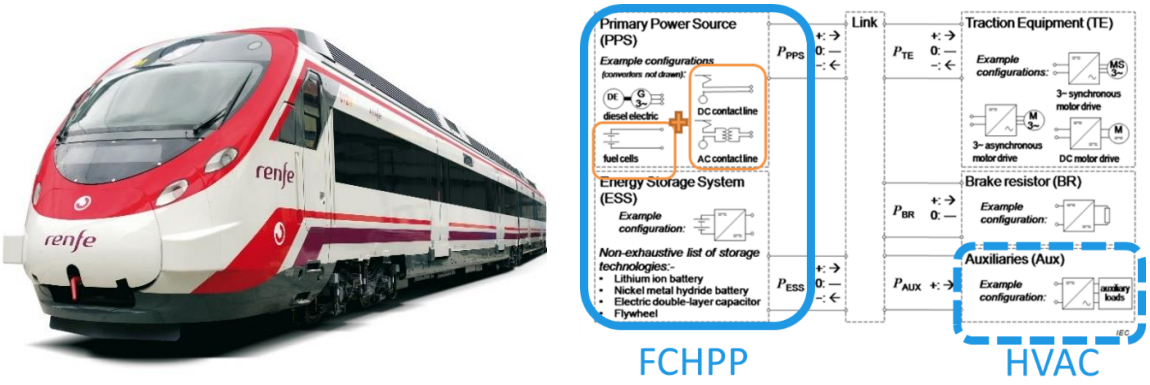

Figure 2: BiMode Demonstrator train and FCHPP architecture as series hybrid system based on [2], modified

Within the FCH2RAIL project the novel FCHPP will be implemented in an existing RENFE operated CAF regional EMU train (Figure 2 left). This redesigned Demonstrator train will then be extensively tested on tracks of the Spanish rail network managed by Administrador de Infraestructuras Ferroviarias (ADIF) and also running on Portuguese tracks managed by Infraestruturas de Portugal (IP). AIDF and IP are both partners of the FCH2RAIL consortium. eventually authorization with cross acceptance for 3 EU countries to be achieved during the project duration.

4. FCH2RAIL results in the first project year

Since the launch of the FCH2RAIL project in January 2021, important steps have been taken towards the bi-mode fuel cell hybrid train demonstrator. The project is implemented according to the plan and within the first project year 15 deliverables have been created, with three public deliverables published on the project webbsite www.fch2rail.eu.

In *WP1 - Generic FC Train Requirement Specifications and Concept* the relevant use cases for hybrid bi-mode vehicles have been analysed. This includes for example a study of the electrification of the Spanish railway network and the vehicles typically used on the non-electrified sections [3]. As a result of WP1, the high-level requirements for the hydrogen train and its operation, covering the vehicle and the infrastructure, have been defined. The results have been published in the public deliverable *D1.3 Report on generic requirements for bi-mode fuel cell hybrid trains* [4]. The FCHPP concept is based on the use of hydrogen, hence the hydrogen refuelling and storage requirements for rail vehicles have also been gathered in WP1. The deliverable *D1.5 – Hydrogen refuelling and storage requirements for rail vehicles* [5] summarizes the hydrogen refuelling requirements and evaluates different hydrogen on-board storage systems as well as supply concepts and layouts for hydrogen refuelling stations (Figure 3).

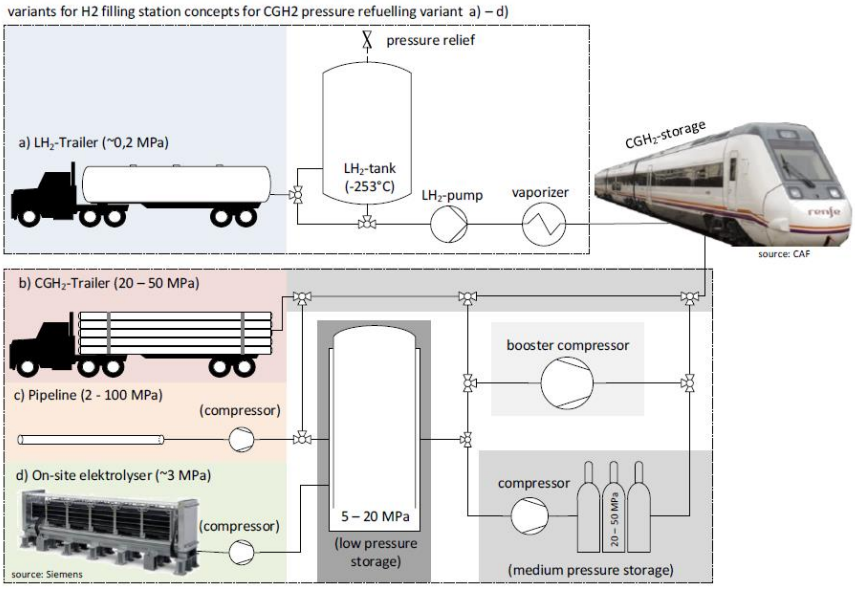

Figure 3: Different HRS layouts and hydrogen supply variants [5]

WP2 - FC powered Train Demonstrator, Architecture and Concept focuses on the integration of the Fuel Cell Hybrid Powerpack (FCHPP) in the demonstrator train. It started with the generic requirements developed in WP1 and adapted them to the CIVIA train that is used as a demonstrator in the project. The demonstrator use cases and performance requirements have been identified and the feasibility of the FCHPP integration in the train demonstrator has been evaluated. The results of these tasks have been documented in the deliverable *D2.1 - Requirements Specification for a Bi-mode FCH Multiple Unit*. The public deliverable *D2.2 Train – FCHPP interface, block schematic* [6] depicts the architecture (Figure 4) and generic interfaces required for the installation of the FCHPP and defines the key aspects and codes of practices to be considered to ensure a proper and safe integration of the FCHPP in a generic train.

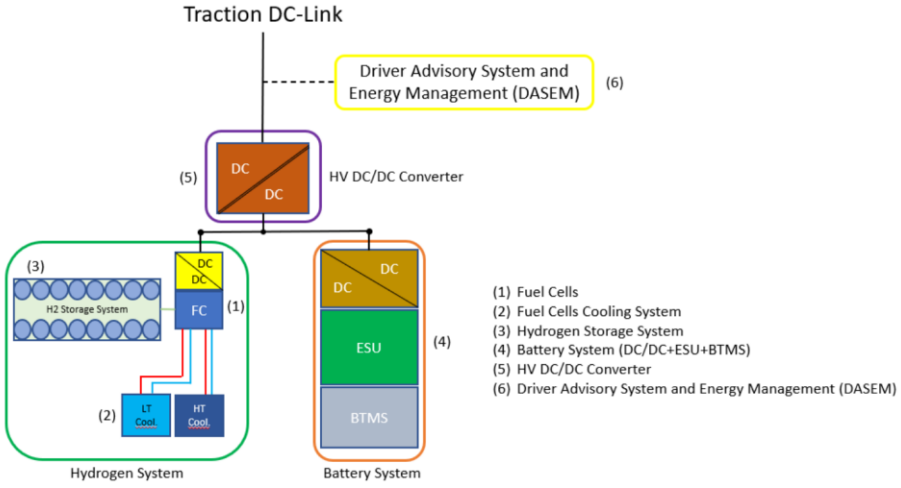

Figure 4: FCHPP Architecture [6]

In parallel, *WP 3 – FC Hybrid Powerpack Development* is advancing in the definition of the modular and scalable FCHPP. The project team started to carry out the technological development of the different critical subsystems of the FCHPP. Until today, WP3 has developed a scalable and modular architecture for the FCHPP and defined the interaction and interfaces between the main subsystems (fuel cells, hydrogen storage, energy storage and high voltage DC/DC converters). Deliverable *D3.1 - FCHPP architecture, interfaces and functions* has been finalised and submitted to the EU Funding and Tenders Portal at end of June 2021.

For *WP 4 Implementation and Test of FC Hybrid PowerPack* Toyota Motor Europe has built, tested and delivered 6 fuel cell modules (Figure 5). The modules are of the latest Gen2 technology in a flat module configuration allowing the most efficient integration in the demonstration train's roof. Three of the modules have already been delivered to the Spanish National Hydrogen Centre CNH2 in January 2022. These fuel cell modules will first be tested together with the batteries in the full system on a test bench, before moving to CAF. The remaining 3 modules are planned to be delivered directly to CAF by mid-February 2022, where all 6 modules will be installed in the demo train.

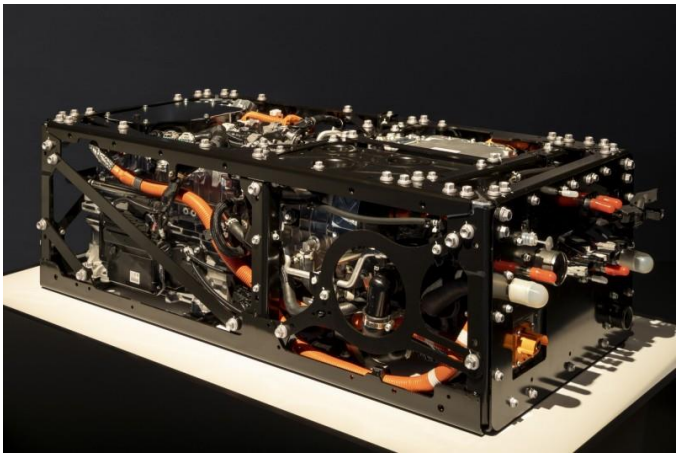

Figure 5: Toyota Gen2 fuel cell module delivered to the project partners CNH2 and CAF [7]

In *WP5 Demonstrator Integration, Testing and Homologation*, the milestone *MS5.1 Train Demonstrator Arrival in CAF* [8], which was originally planned for end of January 2022, could already be achieved in November 2021. Figure 6 shows the CIVIA train that will be used to demonstrate and homologate the FCHPP. The photo was taken after hand-over of the train from RENFE to CAF in the CAF factory in Zaragoza (Spain). The hand-over was accompanied by several tasks such as dynamic and static testing of the CIVIA unit.

Figure 6: CIVIA commuter train used as demonstrator after hand-over from RENFE to CAF [8]

The aim of *WP7 - Normative Framework* is to develop the fundamental basis of a normative framework for the use of hydrogen technology in different kinds of railway applications across Europe. In order to generate the necessary momentum in the railway community, the so called *WP7 network* with external standardisation experts has been formed. In WP7 the important milestone *MS7.1 – Critical interfaces with stakeholders* has been achieved at end of September 2021. This milestone depicts the critical interfaces between the hybrid fuel cell train and the stakeholders involved from construction to operation.

Last but not least the safety management for the project, located in *WP9 – Project Management*, created the deliverable *D9.3 Safety Plan Draft* by end of April 2021. It describes the safety management for the complete FCH2Rail project and establishes the safety processes. These safety processes assure that the train and hydrogen refuelling station developed in the project comply with the requirements defined in the European safety management framework. The safety plan was shared with the European Hydrogen Safety Panel (EHSP) and will be continuously updated during the project lifetime.

5. Conclusion

This paper summarizes the approach, objectives and results achieved in the first project year in the EU funded FCH2RAIL project. In general, the project was implemented fully in line with the plan as described in the grant agreement. The first year of the project was strongly dedicated to the analysis of use cases, the definition of requirements and the development and refinement of technical and administrative concepts for the project implementation. In 2022, the second project year, FCH2RAIL will dive deeper into the implementation of the Fuel Cell Hybrid PowerPack (FCHPP) with the test of component and subsystem assemblies in laboratory environment, providing the necessary background for the implementation of the systems on the demonstrator train in the following project months.

Acknowledgment

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