D4.2. FC Hybrid PowerPack commissioning

WP4 – Implementation and Test of FC Hybrid PowerPack

Task 4.2 – FC Hybrid PowerPack assembly and commissioning

Author	Jose María Olavarrieta, CNH2	
Phone number, E-mail	+34 926420682, Josemaria.olavarrieta@cnh2.es	
Date	11/10/2022	
Document ID	FCH2RAIL-615010822-381	
Document status	x	Draft prepared for final review within task/WP
	x	Finalised draft document at task/WP level
	x	Document after quality check
	x	Document approved by SC
	x	Document approved by TMT
	x	Document submitted to FCH-JU

Dissemination level	
PU: Public	x
CO: Confidential, for members of the consortium only (including the Commission Services):	

Clean Hydrogen Partnership
Co-funded by the European Union

Document status history

Status description	Date	Partner	Status code in filename
Draft prepared for final review within task	11/10/2022	Jose Maria Olavarrieta, CNH2	Draft_final_review_task
Draft prepared for final review within WP	11/10/2022	Jose Maria Olavarrieta, CNH2	Draft_final_review_WP
Finalised draft document at WP level	04/11/2022	Jose Maria Olavarrieta, CNH2	WP_final_draft
Document after quality check	22/11/2022	Florian Kühlkamp, DLR	QC
Document approved by SC	09/12/2022	SC	Approved_SC
Document approved by TMT	09/12/2022	TMT	Approved_TMT
Document submitted to FCH-JU	21/12/2022	DLR	Submitted

Contributions table

Partner	Contribution
CNH2	Test bench video development and deliverable development
CAF	Support of the test bench, review of the test bench video and review of the deliverable and provider of intro and outro of the video. Supplier of the OESS, DCDC converter, HT/LT cooling systems for fuel cells (FCs) and the electronic control system. Drawing of electrical diagrams, installation of wiring and connection of equipment. Commissioning of electronic communication systems, monitoring and registration tools. Test script programming.
DLR	Review of the test bench video, review of the deliverable and quality check
TME	Support of the test bench, review of the test bench video and review of the deliverable. Supplier of three fuel cell (FC) modules for the test bench

This project has received funding from the 'Fuel Cells and Hydrogen 2 Joint Undertaking' (now 'Clean Hydrogen Partnership') under Grant Agreement No. 101006633. This 'Joint Undertaking' receives support from the European Union's Horizon 2020 Research and Innovation program, Hydrogen Europe and Hydrogen Europe Research.

Clean Hydrogen Partnership
Co-funded by the European Union

Executive summary

One of the main goals of the FCH2Rail project is to develop a fuel cell hybrid propulsion system. Therefore, it is important to gain a comprehensive understanding of its operational behaviour.

The acquisition of such knowledge is part of WP4 '*Implementation and Test of FC Hybrid PowerPack*'. Therefore, in WP4, one of two power packs will be installed on a test bench in the CNH2 test facilities and extensively tested in the course of the work package.

The steps required to achieve this goal are divided into three tasks. These cover the installation, operation and operational evaluation of the system. This document '*D4.2 - FC Hybrid PowerPack commissioning*' deals with the integration of the battery pack, the DC/DC converter, the dissipative electronic load as well as the energy management system which controls the test bench.

In the first step, the onboard energy storage system (OESS), its cooling system and its own DC/DC converter are mechanically, hydraulically and electrically connected to the components already installed. The high voltage DC/DC converter is then added to the system. Additionaly, a 650 kWe electronic load is added, which imposes the power demand on the system. The entire system is completed by the installation of an electronic energy management and control system that makes it possible to implement the system's operating strategy. Once all the necessary equipment is installed, the FCHPP functionality is tested to ensure that is fully functional for the upcoming tests.

The core element of this public deliverable is the live demonstration of the aforementioned steps in a video: https://youtu.be/mC7EGb9VA7w .

The video is the real demonstrator of tasks 4.1 and 4.2 and this document contains a brief description of the activities performed.

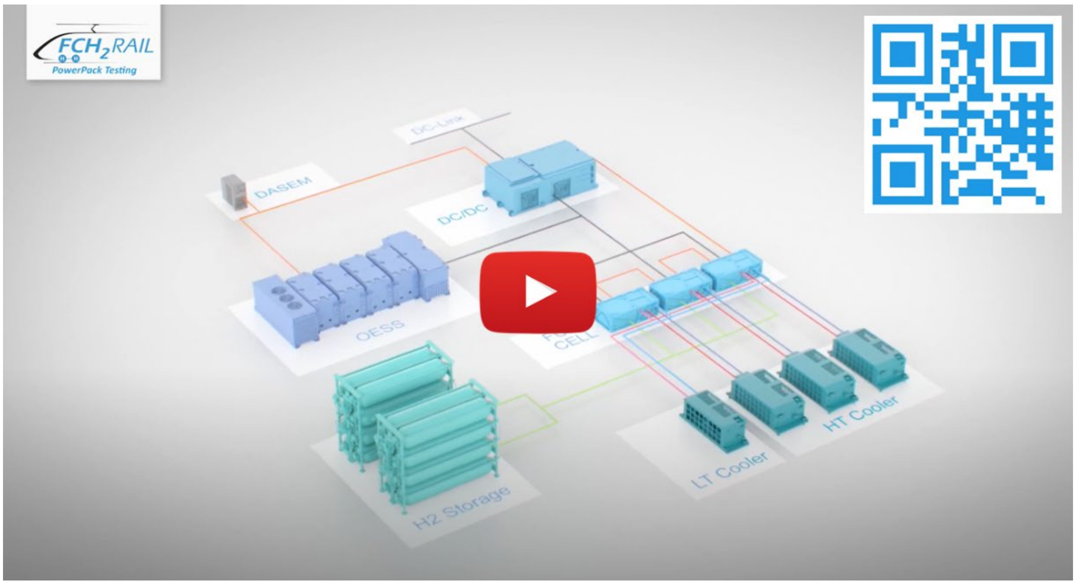

Figure 1: Clip of the deliverable's live demonstration and QR code

Glossary of terms

Abbreviations	Description
BMS	Battery Management System
CCU	Central Control Unit
ESU	Energy Storage Unit
FCHPP	Fuel Cell Hybrid Powerpack
OESS	Onboard Energy Storage System
TCMS	Train Control & Management System

Acronyms	Description
CAF	Construcciones y Auxiliares de Ferrocarriles
CAF PA	Construcciones y Auxiliares de Ferrocarriles. Power & Automation
CNH2	Centro Nacional del Hidrogeno
GA	Grant Agreement
FCH2Rail	Fuel Cell Hybrid PowerPack for Rail Applications
TME	Toyota Motor Europe

Clean Hydrogen Partnership
Co-funded by the European Union

Contents

1. Placement of electronic devices

1.1 Installation and commissioning of OESS

The OESS is one of the main components or block of devices of the power pack which consists on the integration of the four batteries, their cooling system and the DC/DC converter for the OESS system.

Figure 2 shows the OESS in their final placement in the power pack area.

- The first block in the following figure is the DC/DC converter and its own power electronics control unit.
- The four battery modules (or ESUs) are the four blocks in the middle of the pack. They form a powerful battery pack that provides energy when the train is moving and stores energy when the train is braking. Each ESU has its own BMS control unit.
- The last pack, at the bottom of the OESS pack, corresponds to the battery pack cooling system.

Figure 2: Placement and commissioning of the OESS

Each one of the two CAF Power&Automation's onboard energy storage systems (OESS) provides 522 kW and 119.2 kWh. Small-sized, low weight lithium ion cells are connected and the cooling system is integrated.

Following the mechanical and electrical installation, and after being able to communicate the CCU for TCMS with the OESS, the commissioning took place delivering satisfactory results where the system was functioning correctly and as expected and also makes it possible to manage the energy produced by the fuel cells, requested by the system and going to the electronic load respectively.

Clean Hydrogen Partnership
Co-funded by the European Union

1.2 Installation and commissioning of the high voltage DC/DC converter

In the same way as with the OESS, the installation of the high voltage DC/DC converter had to be carried out. Figure 3 shows this equipment in its final placement in the power pack system area.

Figure 3: Placement and commissioning of the DC/DC converter

After the placement of the DC/DC converter, the installation of the wiring that precedes the commissioning of this element was carried out. During the installation, the high voltage DC/DC converter is ready to manage the low-voltage energy values from the fuel cell and battery packs. This voltage is increased to the high-voltage level demanded in test or railway profiles in accordance with the requirements of high-voltage rail lines where the catenary is installed.

Clean Hydrogen Partnership
Co-funded by the European Union

1.3 Installation and commissioning of the dissipative electronic load

To carry out any testing or commissioning that requires energy, the use and implementation of an element that is capable of managing the required amount of energy must be provided. For this purpose, a dissipative electronic load bank is integrated in the fuel cell hybrid power pack to play the role of the train and become an energy consuming system.

Figure 4: Positioning and commissioning of the dissipative electronic load bank

As there is no train in the laboratory, an electronic load bank that is able to dissipate up to 650 kWe when working at full load consumes the electric power generated by the power pack.

1.4 Electronic control of the test bench

This sub-chapter covers the control electronics of the test bench that CAF PA has developed, implemented and optimised during the test period with excellent results for application as the final control management system for the train. This system involves several different elements such as:

- CCU (main bus communications controller)
- Beckhoff PLC system that records the data as well as controlling the system taking into account the data registered instantaneously from the parameters of the system
- IO signals controller and monitoring/recording devices

Clean Hydrogen Partnership
Co-funded by the European Union

All these devices were integrated with the electronic control system developed by CNH2. The final result was very satisfactory and this system from CAF PA was used to record some parameters of the batteries, fuel cell modules, etc. with CAF PA's monitoring and registration programs.

Figure 5 shows the electronic control system being implemented and commissioned by colleagues of CAF PA as part of the global commissioning process.

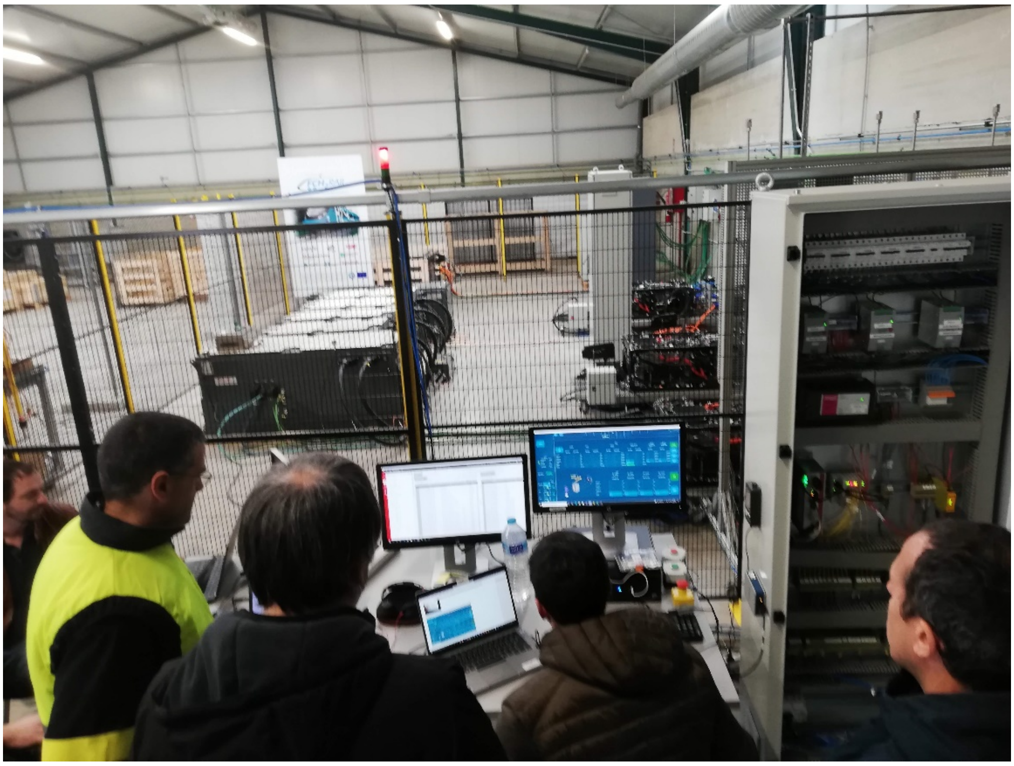

Figure 5: Commissioning of the electronic control system by CAF PA colleagues

Clean Hydrogen Partnership
Co-funded by the European Union

2. Commissioning of the fuel cell hybrid power pack

Upon reaching this point where all the main equipment, systems, subsystems, electrical wiring, mechanical, pneumatic and hydraulic pipelines are connected, interconnected and ready to be used as a complete system, it was possible to carry out the commissioning of the fuel cell hybrid power pack.

Figure 6, Figure 7 and Figure 8 show the different steps of progress of the fuel cell hybrid power pack commissioning process up to the final stage where the complete system is finished and ready to be used in all the planned and necessary tests, both for characterisation of the system and optimisation of the energy management system.

Figure 6: Commissioning of the fuel cell hybrid power pack (I)

Clean Hydrogen Partnership
Co-funded by the European Union

Figure 7: Commissioning of the fuel cell hybrid power pack (II)

Figure 8: Commissioning of the fuel cell hybrid power pack (III)

Clean Hydrogen Partnership
Co-funded by the European Union

Figure 9: Start-up of the fuel cell hybrid power pack

Clean Hydrogen Partnership
Co-funded by the European Union

3. Conclusions

The main conclusions determined from the task developed and explained in the previous paragraphs are as follows:

1. Regarding the individual placement and commissioning of the equipment:
    - They were placed in a suitable area, very close to each other, and connected and interconnected both electrical and mechanically
    - The equipment was ready to be used as part of the whole power pack system
    - No concerns or unexpected issues were detected

2. Regarding the commissioning of the fuel cell system power pack:
    - The fuel cell hybrid power pack was commissioned and all the elements were interconnected, integrated and working as a whole
    - All the concerns and issues that appeared were fully resolved and measures to avoid any other problems were implemented

3. Finally, all the equipment was tested together in a full commissioning test that provided a very good final result, leaving the power pack ready for use on the test bench and any necessary tests.

4. Complex systems like the fuel cell hybrid power pack require extensive testing before they are integrated into the train. A complete power pack was installed and tested comprehensively in CNH2's facilities.

5. Thanks to all the good work and collaboration of the FCH2RAIL partners, the integration of the power pack in the test bench was realised very quickly and professionally. The commissioning tests showed that the entire power pack works as expected and provides its full functionality. The energy management has to be optimised and tested before integration into the train in order to save costs and time.

Clean Hydrogen Partnership
Co-funded by the European Union

4. References

[1] European Comission, “Grant Agreement Number- 101006633 - FCH2Rail,” 2020.

[2] Consortium FCH2Rail Project, “Consortium Agreement FCH2Rail,” 2020.

A.1 List of figures

A.2 List of tables

Clean Hydrogen Partnership
Co-funded by the European Union