D1.3 Interface definition

nExt geNeration 1200V eLectric hIGH volTage powErtraiN

Horizon Europe | HORIZON-CL5-2024-D5-01

Integration and testing of next generation post-800V electric powertrains

(2ZERO Partnership)

Coordinator: Hannes Lacher (AIT Austrian Institute of Technology GmbH)

This project receives funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101192573 (ENLIGHTEN).

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

PROJECT INFORMATION

Project Number	101192573
Project Acronym	Enlighten
Project Full title	Next Generation 1200V Electric High Voltage Powertrain
Project Start Date	01 January 2025
Project Duration	48 months
Funding Instrument	Horizon Europe / HORIZON Research and Innovation Actions
Call	CL5-2024-D5-01-02
Topic	Integration and testing of next generation post-800V electric powertrains (2ZERO Partnership)
Coordinator	Austrian Institute of Technology

DELIVERABLE INFORMATION

Deliverable No.	D1.3	
Deliverable Title	Interface definition	
Deliverable Type	Report	
Dissemination level	Public	
Written By	Stefano Orlando / MAT	Aug 2025
Checked by	Hannes Lacher / AIT	Sept 2025
Approved by	Hannes Lacher / AIT	Sept 2025
Status	Final	26092025

DOCUMENT HISTORY

Version	Date	Who	Remarks
0.1	05.09.2025	Stefano Orlando (MAT)	Content
0.2	15.09.2025	Stefano Orlando (MAT)	First Review
1.0	26.09.2025	Hannes Lacher (AIT)	Approval

TABLE OF CONTENTS

PROJECT ABSTRACT

ENLIGHTEN aims at developing, integrating and testing a next generation post 800V electric vehicle powertrain with an indicative voltage level of 1200V. It targets a higher performing, cost optimized and more sustainable drivetrain layout that is also backwards compatible to the existing charging infrastructure with 1000V or 500V respectively. Determining exactly how high the new voltage level should be, to enable expected advantages in a systemic and systematic way is also part of the project. A new voltage level affects the entire sphere of electric mobility, both horizontally (vehicle, charging infrastructure, users, manufacturers) and vertically (OEM, tier1, tier2, single component supplier), hence a deliberate decision is required. To accomplish this an advanced electrical system architecture is presented by the ENLIGHTEN consortium in this proposal on whose basis a specific electric vehicle drivetrain will finally be developed and demonstrated in a C-segment vehicle. The at TRL5 delivered powertrain will consist of a dual voltage battery system and an integrated motor-inverter E-drive system, complemented by an intermediate DCDC converter, an AC and DC capable onboard charger and a power distribution. All power electronic devices will exploit low loss, ultra-fast switching gallium nitride (GaN) semiconductors for highest efficiency and to minimize cooling demand and component size. The dual voltage battery can be switched dynamically from one battery voltage into the other while driving. Through these and other measures, the ENLIGHTEN system delivers significant advances over the 2024 State of the Art. The ENLIGHTEN consortium includes 2 automotive companies, 1 Tier1 supplier and 2 SMEs. Their expertise is leveraged by the partnership with 2 research institutions and 4 academia/universities, constituting an ideal setup for strengthening the competitiveness of the European automotive industry.

PARTNERS

Participant no.*	Participant short name	Participant organisation name	Country
1. Coordinator	**AIT**	Austrian Institute of Technology GmbH	Austria
2.	**EAT**	Eaton	Czech Republic
3.	**POLITO**	Politecnico di Torino (Polito)	Italy
4.	**IFP**	IFP Énergies nouvelles	France
5.	**AU**	Aarhus University	Denmark
6.	**THI**	Technische Hochschule Ingolstadt	Germany
7.	**MAT**	Manifattura Automobili Torino	Italy
8.	**CGD**	Cambridge GaN Devices	United Kingdom
9.	**LT**	Leadtech	Italy
10.	**FMF**	FPT Motorenforschung AG	Switzerland
11.	**ETH**	Eidgenössische Technische Hochschule Zürich	Switzerland

LIST OF ABBREVIATIONS

Acronym / Short Name	Meaning
ABS	Anti-lock Braking System
AC	Alternating Current
BMS	Battery Management System
CAN	Controller Area Network
CCS	Combined Charging System
DC	Direct Current
ESP	Electronic Stability Program
GaN	Gallium Nitride
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
LV	Low Voltage
PDU	Power Distribution Unit
SOC	State Of Charge
SOH	State Of Health
VCU	Vehicle Control Unit

EXECUTIVE SUMMARY

This deliverable specifies the interfaces required to integrate the ENLIGHTEN powertrain into a Hyundai Ioniq 5 donor vehicle. The objective is to describe how the newly developed components connect electrically, mechanically, and thermally, and how they interact with retained subsystems of the donor platform.

The ENLIGHTEN architecture is based on a dual-voltage traction battery, reconfigurable between ~1200V (series mode) and ~600V (parallel mode). The battery connects to a new Power Distribution Unit (PDU), which distributes power between the integrated motor–inverter, the intermediate DCDC converter, and the on-board charger. Donor components, such as the 800V → 12V DCDC converter and the HVAC compressor, remain supplied through the regulated 800V domain created by the intermediate converter.

The report presents:

- **High-voltage interfaces**.
- **Low-voltage and signal interfaces** using CAN-bus, managed by a new Vehicle Control Unit (VCU) working in coordination with the donor controllers.
- **Mechanical interfaces** for mounting, drivetrain coupling, and packaging.
- **Thermal interfaces** defining coolant inlet and outlet connections for all new components.

Together, these definitions establish the basis for component development and integration of the ENLIGHTEN demonstrator.

1 SYSTEM ARCHITECTURE

The ENLIGHTEN demonstrator will be developed on the basis of a Hyundai Ioniq 5 donor vehicle, into which a next-generation high-voltage drivetrain will be integrated. The project aims to define, implement, and validate a post-800V electric powertrain architecture with indicative operating voltages up to 1200V. This represents a major step beyond today's solutions while maintaining compatibility with the existing 400V and 800V charging infrastructure.

The overall system architecture, presented in Deliverable D1.2 and shown in Figure 1, combines newly developed ENLIGHTEN components with selected subsystems carried over from the donor vehicle. The colours in the figure indicate which consortium partner is responsible for each subsystem, as well as which components remain carry-over from the donor vehicle.

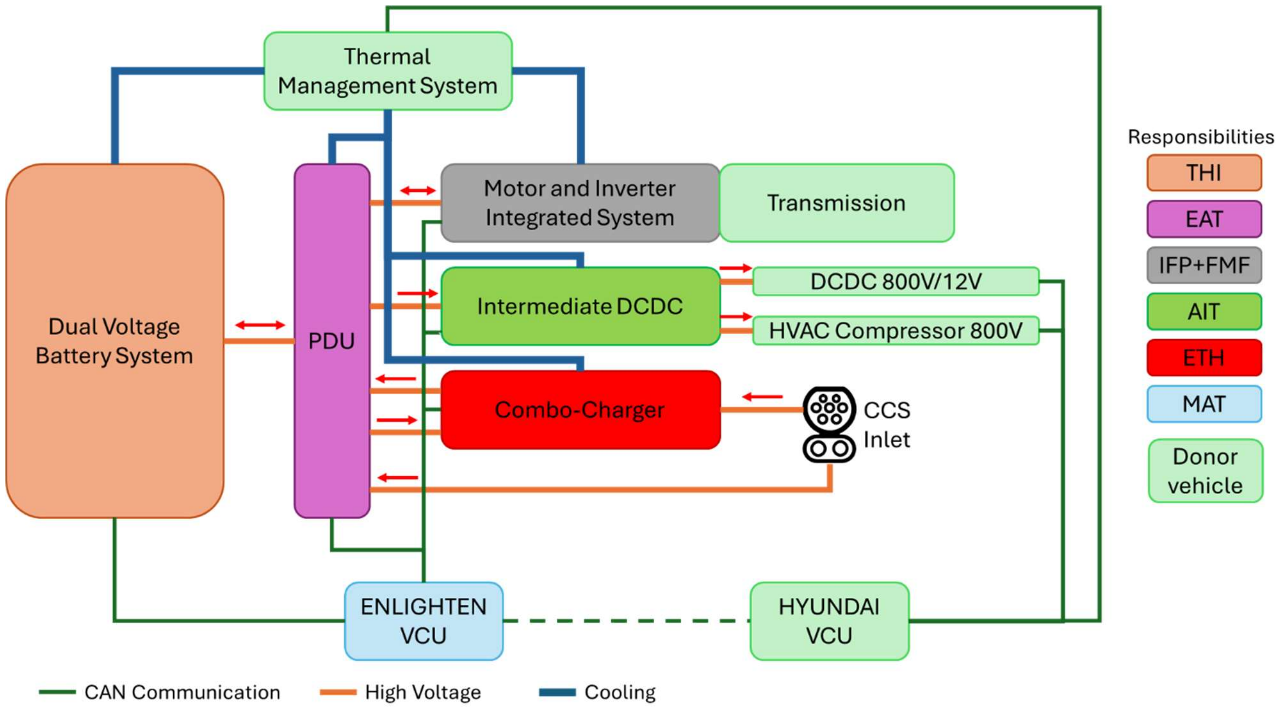

Figure 1: ENLIGHTEN system architecture

At the centre of the architecture is a dual-voltage traction battery system, composed of modules arranged in two strings. The system supports two operating modes:

- **Series configuration (~1200V):** both strings are connected in series, reducing current levels and conduction losses during high-speed driving. This mode also enables ultra-fast charging at future 1200V charging stations.
- **Parallel configuration (~600V):** both strings are connected in parallel, lowering the system voltage below 1000V. This mode improves efficiency in low-speed urban driving and ensures compatibility with today's DC fast chargers up to 1000V.

This reconfigurable battery concept enables efficiency improvements for different driving conditions, while remaining backwards compatible with existing charging standards.

The battery is connected to the Power Distribution Unit (PDU), which manages power flow to the various subsystems. From the PDU, energy is supplied to the newly developed integrated motor–inverter system. The inverter uses GaN-based power electronics for faster switching and reduced losses, directly controlling the ENLIGHTEN traction motor that remains mechanically coupled to the donor transmission.

An intermediate DCDC converter is introduced to adapt the variable battery voltage to a regulated 800V bus. This bus supplies the carry-over 800V → 12V DCDC converter from the Ioniq 5, supporting the vehicle's low-voltage systems, and also powers the donor HVAC compressor.

Two modes of charging are handled by a new on-board combo-charger interfacing with the Combined Charging System (CCS) inlet. The charger supports both AC (400 Vac) and DC (≤500 V) charging, with its outputs routed through the PDU to the traction battery.

Beyond the HV network, the architecture defines additional interfaces:

- **Communication interfaces:** A new Vehicle Control Unit (VCU) supervises all ENLIGHTEN components over CAN-bus. The donor Hyundai VCU continues to manage existing subsystems carry over from the donor vehicle. Ideally, data exchange between the two VCUs would be established to maintain coordination with these donor systems. However, it is uncertain whether such communication can be achieved in practice. OEM CAN networks are often encrypted or otherwise protected, making access to the required signals difficult without manufacturer support. For this reason, the dashed-line connection shown in Figure 1 represents an intended but not yet guaranteed interface.
- **Thermal interfaces:** All new ENLIGHTEN components require liquid cooling, with defined inlet and outlet ports. Pumps, radiators, and reservoirs from the donor thermal management system will be reused, but the detailed routing of cooling loops has not yet been defined and will be finalised following cooling simulation results.
- **Mechanical interfaces:** New subsystems will be mounted using existing donor attachment points or custom brackets, ensuring secure installation, and compatibility with the Hyundai Ioniq 5 chassis layout.

With this configuration, the ENLIGHTEN demonstrator will provide a real-vehicle platform to evaluate GaN-based power electronics, dual-voltage battery operation, and high-efficiency power distribution. At the same time, it remains fully compatible with the existing charging infrastructure. Based on the final system architecture (see Deliverable D1.2 and Figure 1), the following chapters describe in detail the interfaces of each component, including, communication, high-voltage (HV), low-voltage (LV), cooling, and mechanical aspects.

2 HIGH VOLTAGE INTERFACES

High-voltage (HV) interfaces form the backbone of the ENLIGHTEN powertrain, ensuring the safe and efficient transfer of energy between the dual-voltage battery system, the power distribution unit (PDU), the integrated e-drive, auxiliary converters, and the charging system. All HV connections must guarantee reliable operation at voltages up to ~1200V, while maintaining compliance with automotive safety standards.

The following sections describe the HV interfaces of each major component.

2.1 INTEGRATED MOTOR AND INVERTER SYSTEM

The ENLIGHTEN traction system combines the inverter and motor into a single e-drive unit, removing the need for internal HV cabling between the two subsystems. The only HV interface is the bidirectional DC connection between the PDU and the inverter.

This interface will be implemented with HV connectors designed to withstand the required voltages and peak currents.

The inverter will convert HV DC power from the PDU into three-phase AC to drive the motor. During regenerative braking, AC from the motor will be converted back into HV DC and returned to the PDU for storage in the battery.

2.2 BATTERY SYSTEM

The dual-voltage traction battery system will be the vehicle's main energy source. Its sole external HV interface will be the bidirectional DC link to and from the PDU.

The interface will be realized with shielded HV cables and connectors. Internally, the battery will integrate fuses and safety switches to protect against short circuits and overcurrent. The Battery Management System (BMS) will continuously monitor insulation resistance to detect possible leakage currents to ground, ensuring safe operation under all conditions.

2.3 COMBO CHARGER

The combo-charger will provide, together with the PDU, the HV interface between the vehicle and the external charging infrastructure via the CCS inlet. It will be developed with dual input from the CCS inlet, accommodating both AC for standard charging and DC for charging at 500V charging stations, coming not directly from CCS inlet, but through the PDU. The charger's single output will be connected to the Battery System again via the PDU.

- **AC charging path**: The CCS inlet will deliver 400Vac to the charger. Inside the charger, the AC input will be rectified to HV DC (600V), which will then be routed to the battery system through the PDU. The HV interface on this path will therefore consist of a unidirectional AC link from the CCS inlet to the charger and a unidirectional DC link from the charger output to the PDU.
- **DC charging path**: During DC charging at ≤500Vdc, HV DC from the CCS inlet will first pass through the PDU, which will provide switching, fusing, and safety isolation. From the PDU, the DC input will be connected to the charger. After conditioning, the regulated HV DC will be routed back through the PDU and onward to the battery. The HV interfaces here will therefore include both an input and output link between the charger and the PDU. The DC connection from charger to PDU is shared between the two charging paths.

All charger HV connections will use shielded high-voltage cables and connectors.

2.4 INTERMEDIATE DCDC

The intermediate DCDC converter will deliver power to auxiliary high-voltage systems. It will provide a unidirectional step-down interface between the high-voltage battery domain (up to ~1200V) and the original 800V auxiliary domain. Its HV input will consist of a single unidirectional DC link from the PDU, while its HV output will provide a regulated 800V DC link to supply the most probably carry-over 800V → 12V DCDC converter and the HVAC compressor of the donor vehicle.

The HV interfaces will be realized with shielded high-voltage connectors. A core requirement of the converter will be the implementation of robust galvanic isolation between its HV input and output, preventing electrical faults from propagating across domains and ensuring the integrity of both the HV and LV networks. In addition, insulation monitoring on the 800V side will be investigated to guarantee safe and reliable operation of the auxiliary domain.

2.5 PDU – POWER DISTRIBUTION UNIT

The power distribution unit will act as the central HV distribution and protection hub, interconnecting all major high-voltage components and ensuring their safe operation.

The HV interfaces of the PDU will include:

- Bidirectional link to the battery system
- Bidirectional link to the integrated motor–inverter unit, enabling both traction power delivery and regenerative braking energy recovery
- Unidirectional output to the intermediate DCDC converter
- Unidirectional input from the combo charger

- Unidirectional output to the combo charger for <500V DC charging from CCS inlet passing through the PDU before entering the charger
- Direct input from the CCS inlet for DC charging

All PDU interfaces will be realized with HV connectors. The PDU will also house key safety elements such as main fuses and contactors, enabling controlled isolation of the entire HV system during faults, emergencies, or maintenance.

3 LOW VOLTAGE AND SIGNAL INTERFACES

The low-voltage (LV) and signal interfaces manage communication, control, and monitoring across the ENLIGHTEN powertrain. While the HV network transfers energy, the LV and signal network ensures coordinated operation and safety across all components. Communication will primarily rely on CAN-bus, supplemented by discrete wiring for interlocks, wake-up lines, and dedicated safety signals.

A newly developed Vehicle Control Unit (VCU) will supervise all ENLIGHTEN components, handling control, diagnostics, and coordination. The original Hyundai VCU will remain in charge of donor vehicle systems such as ABS/ESP, HVAC, the 12V DCDC converter, and power steering. Signal exchange between the two VCUs will allow new and existing systems to operate in a coordinated manner.

The following sections describe the LV and signal interfaces of each newly developed component.

3.1 INTEGRATED MOTOR AND INVERTER SYSTEM

The integrated e-drive unit will communicate with the new VCU via CAN-bus. The VCU will send torque requests, speed references, and mode commands, while the inverter will report diagnostic data including voltage, current, temperature, and fault states. Regenerative braking status signals will also be transmitted, enabling the VCU to coordinate braking energy recovery with the vehicle's existing systems.

3.2 BATTERY SYSTEM

The battery system will integrate a Battery Management System (BMS) connected to the VCU via CAN-bus. The BMS will provide real-time data such as state of charge (SOC), state of health (SOH), individual cell voltages, and thermal conditions. It will also transmit warnings and fault messages in case of insulation degradation or cell-related issues. The VCU will send control signals for pre-charge, main contactor activation, and switching between series and parallel battery configurations.

3.3 COMBO CHARGER

The combo charger will be supervised by the VCU through a dedicated CAN-bus interface. During charging, the charger will exchange control and diagnostic data with both the VCU and the BMS to regulate voltage and current. It will also provide safety-related feedback such as temperature levels and error codes. Communication with external charging stations via the CCS protocol will not be implemented within this project; instead, AC and DC charging will be carried out under controlled test conditions.

3.4 INTERMEDIATE DCDC

The intermediate DCDC converter will receive its operating commands from the new VCU via CAN-bus. The VCU will control its activation and monitor its output voltage and current. The converter will return diagnostic data including internal temperatures, insulation monitoring results, and fault states. This interface ensures stable operation of the regulated 800V auxiliary domain and its coordination with the donor vehicle's 12V DCDC converter and HVAC compressor.

3.5 PDU – POWER DISTRIBUTION UNIT

The PDU will interface with the new VCU via CAN-bus for system supervision. The VCU will control the main contactors and safety relays, while the PDU will provide diagnostic information on HV current, voltage, fuse integrity, and contactor status. Acting as the central protection hub, the PDU will also generate and forward HV safety events to the VCU, enabling rapid and coordinated responses to faults or emergency conditions.

4 MECHANICAL INTERFACES

The mechanical interfaces define how ENLIGHTEN components are integrated into the donor vehicle, ensuring structural stability, correct drivetrain connection, and serviceability. Each unit must be securely fixed to the chassis or subframes, with appropriate provisions for vibration isolation and accessibility. Rotating elements must guarantee precise alignment and torque transfer. For packaging reasons, the external dimensions of newly developed components are designed to remain comparable to those of the original donor parts.

The following sections outline the mechanical interfaces of each ENLIGHTEN component.

4.1 INTEGRATED MOTOR AND INVERTER SYSTEM

The integrated e-drive will be mounted on the donor vehicle's rear subframe using custom brackets and isolating mounts. Proper alignment and vibration damping will be prioritized to ensure long-term reliability under high torque loads. The motor shaft will couple directly to the donor vehicle's speed reducer, maintaining compatibility with the existing drivetrain. This interface requires accurate concentricity and robust coupling to prevent misalignment, premature wear, or power losses.

4.2 BATTERY SYSTEM

The battery will reuse the donor vehicle's structural casing, preserving the original mounting points to the underbody of the Hyundai Ioniq 5. This ensures compatibility with the vehicle chassis and retains the crash safety characteristics validated in the donor design. Newly developed modules will be integrated inside the existing enclosure without modifying the external attachment geometry.

4.3 COMBO CHARGER

The combo charger will be located inside the vehicle, possibly near the battery pack and CCS inlet. It will be mounted to the chassis using vibration-dampening fixtures, protecting sensitive electronics from mechanical stress. The casing will provide sufficient rigidity to withstand service handling and incidental impacts during vehicle operation.

4.4 INTERMEDIATE DCDC

The intermediate DCDC converter will be probably positioned close to the PDU and battery to minimize cabling. It will be mounted using dedicated brackets designed to absorb vibrations and maintain stable alignment with cooling and electrical connections. The enclosure will be engineered for robustness while ensuring accessibility for maintenance.

4.5 PDU – POWER DISTRIBUTION UNIT

The PDU will be housed in a rigid enclosure mounted near the battery pack to minimize HV cable lengths. It will be fixed using dedicated brackets that provide both stability and accessibility for service. The housing will comply with IP-rated sealing requirements to protect against dust and moisture ingress while withstanding vibration and impact loads during operation.

5 THERMAL INTERFACES

The thermal management system ensures that all high-voltage components operate within their specified temperature limits, safeguarding performance, durability, and safety. In the ENLIGHTEN architecture, all new components require liquid cooling, implemented via dedicated water inlet and outlet ports. The donor vehicle's existing cooling hardware, such as pumps, radiators and reservoirs, will be retained, with integration points for the new subsystems defined during later stages of development.

The following sections describe the thermal interfaces of each component.

5.1 INTEGRATED MOTOR AND INVERTER SYSTEM

The integrated e-drive will be equipped with dedicated water inlet and outlet ports to remove heat from both the inverter electronics and the motor stator. Internal cooling channels will be optimized for effective thermal transfer. The unit will be connected into the donor cooling loop using flexible hoses with standardized connectors, facilitating assembly and service operations.

5.2 BATTERY SYSTEM

The battery will retain the donor vehicle's casing, which incorporates integrated liquid cooling channels. These channels connect to the vehicle's existing thermal loop via standardized inlet and outlet ports, maintaining uniform temperature distribution across the modules. The interfaces remain unchanged from the donor design, with only minor adaptations to hose routing expected to accommodate other new components.

5.3 COMBO CHARGER

The combo charger requires active liquid cooling to manage heat generated during both AC and DC charging. It will feature water inlet and outlet ports compatible with standard hose fittings. Integration into the donor cooling system will ensure sufficient heat removal during high-power operation. The exact placement in the thermal loop will be defined at a later stage, but the interfaces will allow flexible integration.

5.4 INTERMEDIATE DCDC

The intermediate DCDC converter will use liquid-cooled baseplates integrated into its housing. Cooling will be achieved through a water inlet and outlet, connected using standard fittings for compatibility with the donor loop. While the final loop configuration remains under definition, the converter's thermal interfaces will be designed for modular integration and straightforward serviceability.

5.5 PDU – POWER DISTRIBUTION UNIT

The PDU will include liquid cooling channels to dissipate heat from the main contactors and fuses. Water inlet and outlet ports will be provided, with hose connections compatible with the donor vehicle's cooling standards. Depending on the final loop configuration, the PDU may be integrated in series or parallel with other cooled components.

6 CONCLUSION

This document defines the complete set of interfaces for the ENLIGHTEN powertrain demonstrator. Each new component, dual-voltage battery, motor–inverter, intermediate DCDC, on-board charger, and PDU, has been described in terms of its high-voltage, low-voltage, mechanical, and thermal connections.

The interface definitions ensure compatibility with the Hyundai Ioniq 5 donor platform by reusing existing mounting points, cooling hardware, and selected auxiliaries where possible. They also introduce the provisions needed for the new subsystems developed in the project, such as the dual-voltage battery and GaN-based power electronics.

The outcome is a clear framework for detailed design and integration work in the next stages of the project.