ECOCHAMPS

European COmpetitiveness in Commercial Hybrid and AutoMotive PowertrainS

# WP5 D5.3
# IVECO Medium Duty prototype

**EUROPEAN COMMISSION**
**Horizon 2020 | GV-4-2014 | Hybrid Light and Heavy Duty Vehicles**
**GA # 653468**

| | | |
|---|---|---|
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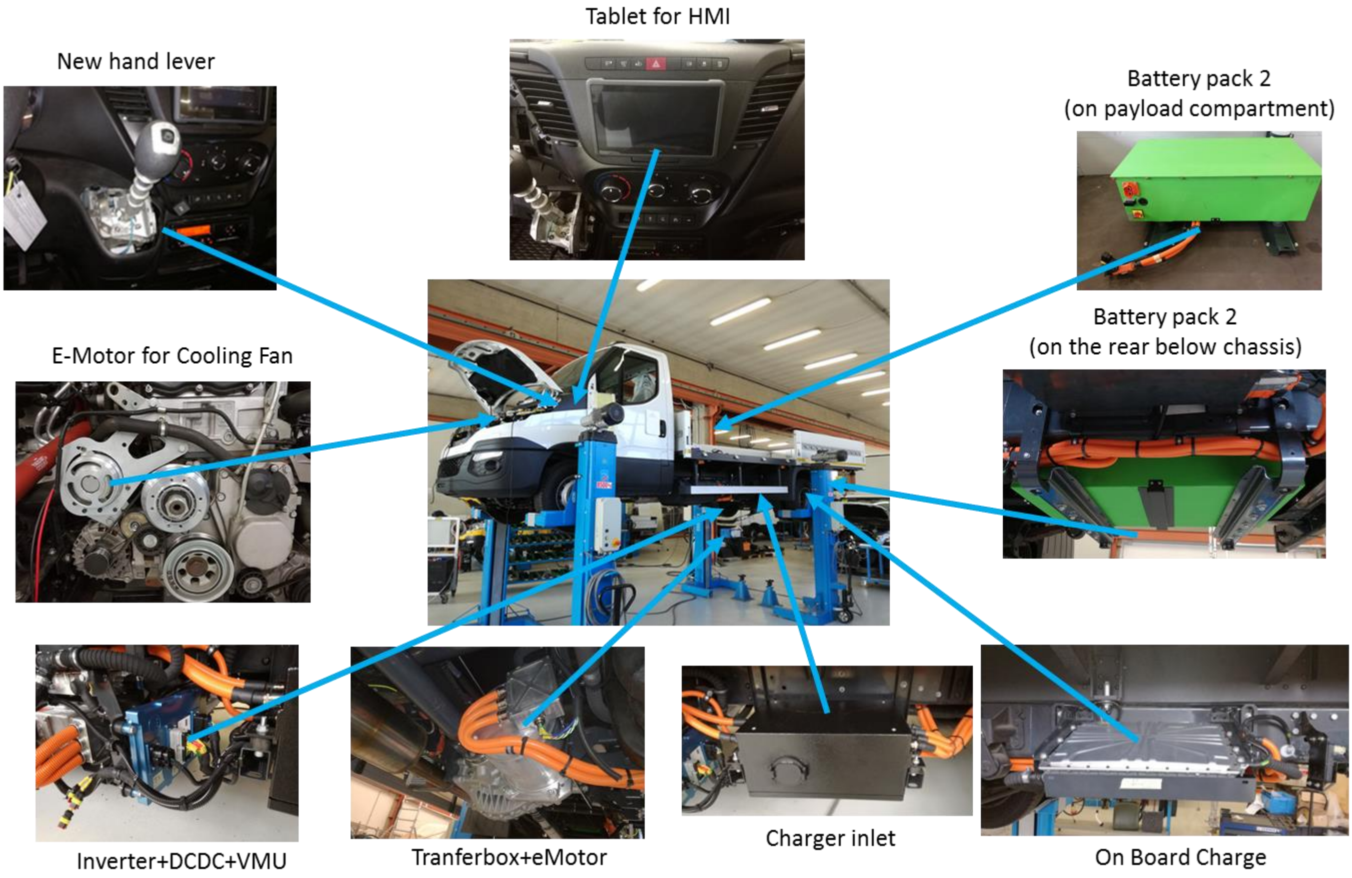
## Publishable Executive Summary

In order to achieve the objectives of the ECOCHAMPS project , within the Work Package 5, a PHEV demonstrator based on a Daily 7 t has been built and equipped with the HV Battery (from partner Bosch), the Transfer Box (from Partner FPT) and with specific EM.

The prototype system architecture, the subsystem components definition and the main requirements were fixed in the first deliverable D5.1 and, according to the contents of the second deliverable D5.2, all the new electrical components have been integrated on the vehicle, from the mechanical, electrical and electronic point of view.

The main targets achieved in the Task 5.3 are:

1. Prototype vehicle build up (Electrical and Mechanical)
2. Start-up and first calibration
    a. Hybrid systems SW calibration
    b. Vehicle Energy Management SW calibration



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# 1 Introduction

The Task **5.3 "Prototype vehicle build up, start-up and calibration"** has the objective to integrate on the demonstrator the hybrid components defined and developed in the previous tasks. In specific, the characteristic of modularity and standardization in term of components design and manufacturing, respect to the technology state of art, should have the intent to fulfil the cost-saving benefit necessary to increase the hybrid market penetration. The integration requirements have taken in to account several influence factors: electric and mechanical performances, lifetime, thermal behaviour, environmental conditions in real use, mechanical and SW interfaces.

At the end, all the components have been fitted in the vehicle, following the design phase achievements. The activities included also the brackets build-up, which assure the components position under the on-road test severe conditions, even if this is considered a proto vehicle.

The Main Task 5.3 includes 2 subtasks:

**5.3.1 Hybrid system: SW calibration**
**5.3.2 Vehicle Energy Management**

As described in the planning below, the deliverable D5.3 (output of the task 5.3) had a delay of one month, due to some issues appeared in the previous tasks. (Main delay reason: eMotor development and delivery).

**Period Highlight:** 23 | Plan | Actual | % Complete | Actual (beyond plan) | % Complete (beyond plan)

| ID | ACTIVITY | PLAN START | PLAN DURATION | ACTUAL START | ACTUAL DURATION | PERCENT COMPLETE | STATUS |
|---|---|---|---|---|---|---|---|
| **WP5** | **Medium Duty Application – IVECO Demonstrator** | 1 | 36 | 1 | 36 | 45% | ☺ |
| Task 5.1 | Hybrid drive design and vehicle concept optimization | 1 | 8 | 1 | 16 | 100% | ☺ |
| Task 5.2 | Component integration into the Hybrid powertrain architecture | 6 | 16 | 6 | 16 | 100% | ☺ |
| Task 5.3 | Prototype vehicle build up, start-up and calibration | 14 | 9 | 14 | 10 | 100% | ☺ |
| Task 5.4 | Testing and fine tuning of the demo vehicle | 22 | 9 | 22 | 9 | 10% | ☺ |
| Task 5.5 | Prototype: final validation and evaluation | 30 | 7 | 30 | 7 | 0% | ☺ |

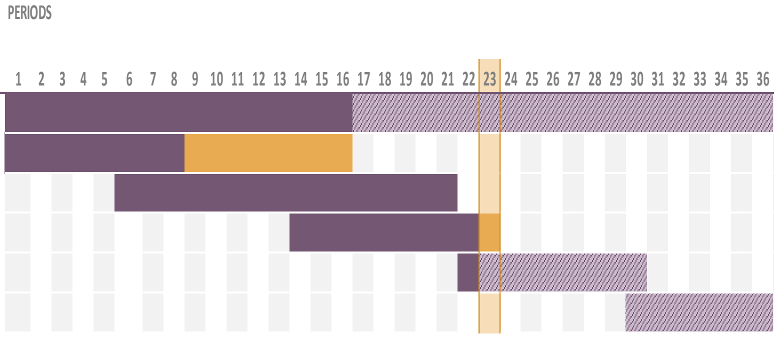


**Figure 1-1 Planning**

The following chapters will focus on the integration of the eDriveline and Battery systems on the IVECO demo vehicle and on the main activities done to achieve this target:

- Mechanical Integration
- Electrical Integration
- SW Control Functions and main Safety Strategies development and testing
- Demonstrator Start-Up and Commissioning.

# 2 Electric Powertrain & HV Components Integration

## 2.1 Mechanical Integration

The main activity of the task 5.3 was, of course, the mechanical and electrical integration of the new hybrid components. Respecting the design developed in the task 5.2, the IVECO-ALTRA team has been able to install all the components as described in the diagram below:

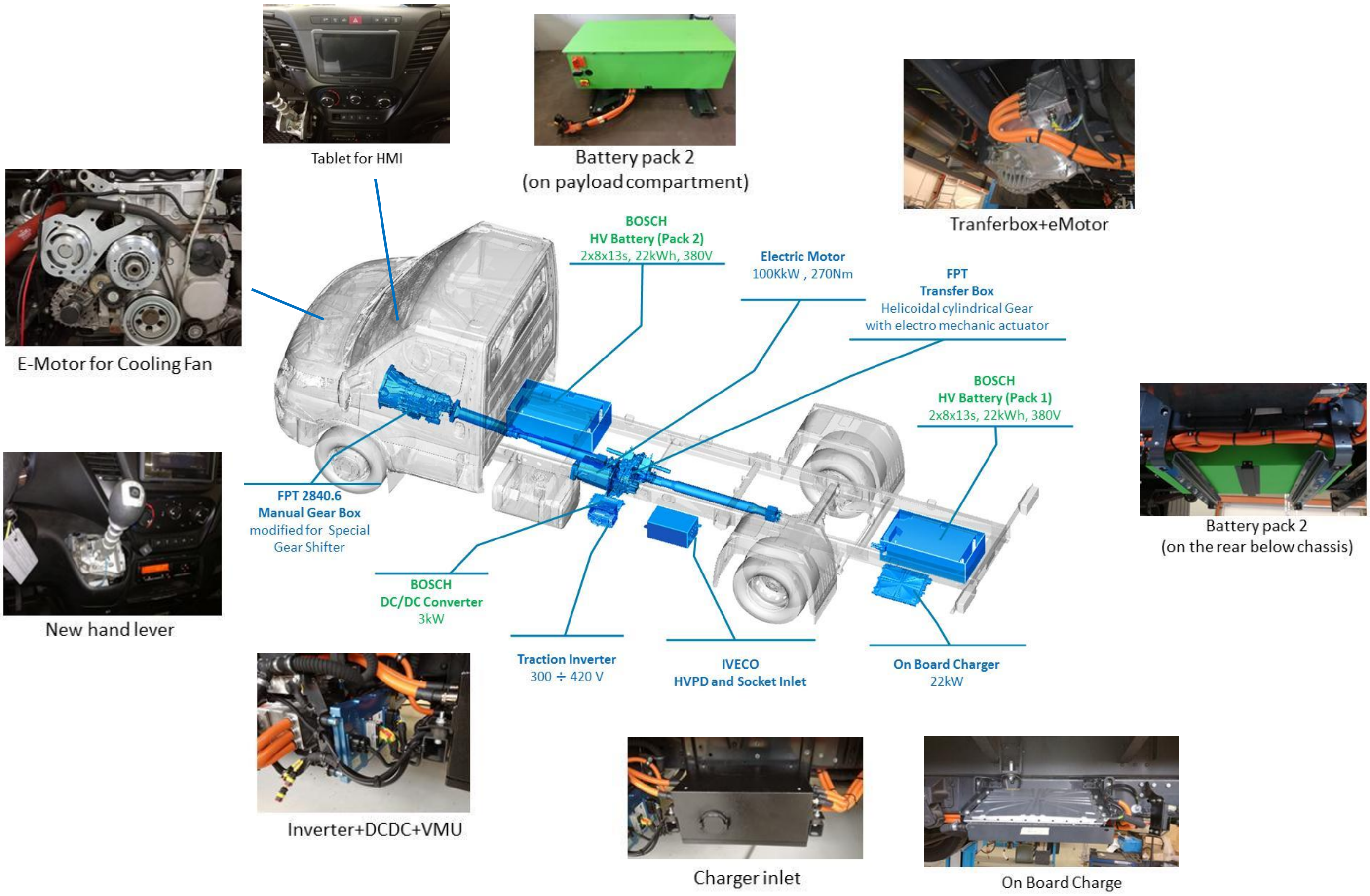


**Figure 2-1 Components Installation Layout**

**Figure 2-2 Demonstrator**

The only variation applied with respect to the initial design is related to the HV battery system cooling circuit; this variation will be described in details in the paragraph 2.3.

In the following table there is a list of the components real weight and the Demonstrator total weight:

| Component/System | Weight [Kg] | note |
|---|---|---|
| BASELINE DIESEL VEHICLE | 3215 | |
| DEMONSTRATOR | 3711 | |
| Battery Pack 1 | 188 | It's different from second pack, because it includes the Master BMS control unit |
| Battery Pack 2 | 185 | |
| Inverter | 7,5 | |
| e-Motor | 58 | |
| DC/DC Converter | 4 | |
| On Board Charger | 12 | |
| Transfer Box | 57,2 | |
| e-motor for Cooling Fan | 5 | |
| Standard Diesel Vehicle components and and HV Wiring | 3194,3 | Cooling Piping, Chassis, Thermal Engine, Gear, NewPropeller shaft, Additional Pumps, Wheels, etc. |

**Table 2-1 Components and Vehicle Weights**

These values show that the Demonstrator Vehicle has an increment of 15% of its curb weight with respect to the base vehicle; this means that, at the end, the target that IVECO had declared, has been respected and it is possible to confirm that we will have only a reduction of the payload not greater than 20%.

In particular, considering the electric driveline components, we can have the following comparison:

| ELECTRIC MOTOR | | | | INVERTER+DCDC | | | |
|---|---|---|---|---|---|---|---|
| | ECOCHAMPS 7t | Daily Electric 5t | Delta | | ECOCHAMPS 7t | Daily Electric 5t | Delta |
| Theoretical volume [mm 3] | 15,3 10^6 | 29,3 10^6 | -47,6% | Theoretical volume [mm3] | 9 10^6 | 9,4 10^6 | -3,3% |
| Weight [Kg] | 58 | 99 | -41,4% | Weight [Kg] | 11,45 | 13 | -11,9% |

**Table 2-2 Components Weights Comparison**

Considering that IVECO target was to reduce electric driveline weight and volume by up to 20% and considering, as reference, the std Daily electric driveline components, we can state that the overall reduction is aligned with the target.

| | INV+MOT+DCDC | | % |
|---|---|---|---|
| | ECOCHAMPS | DAILY ELECTRIC | |
| Weight [Kg] | 69,45 | 112 | -37,99% |
| Theoretical volume [mm 3] | 24,4 10^6 | 38,6 10^6 | -36,86% |

**Table 2-3 Components Weights Overall Comparison**

## 2.2 Electrical Integration

Also from the electrical point of view, the realization on the vehicle respected all the Deliverable D5.2 design elements.

In details, this is the HV components layout:

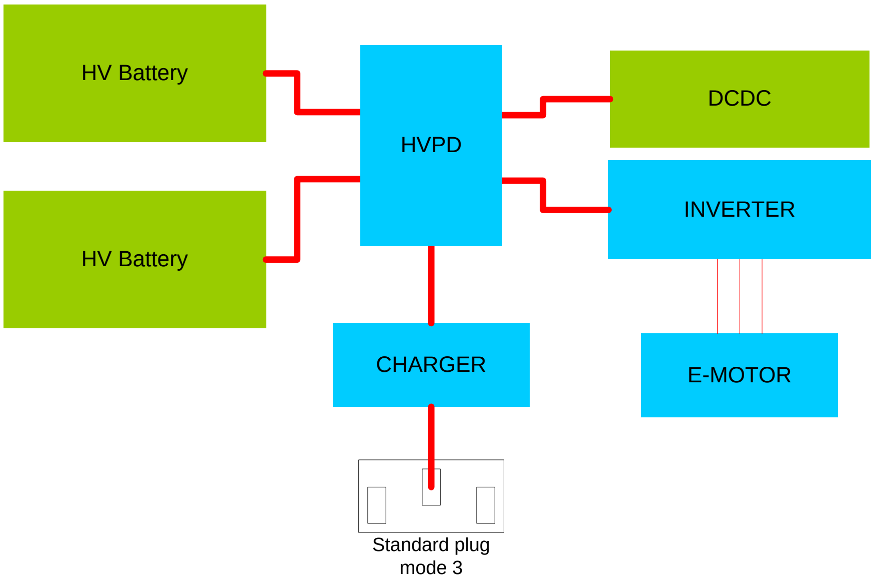


**Figure 2-3 HV Components Block Diagram**

### 2.2.1 HVIL and Safety

Thanks to the Bosch support, IVECO worked with high attention, in order to implement the best HVIL circuit and the better emergency shut down system.

**Figure 2-4 HV Emergency Shut down Installation**

The following functional schema shows the final implementation:

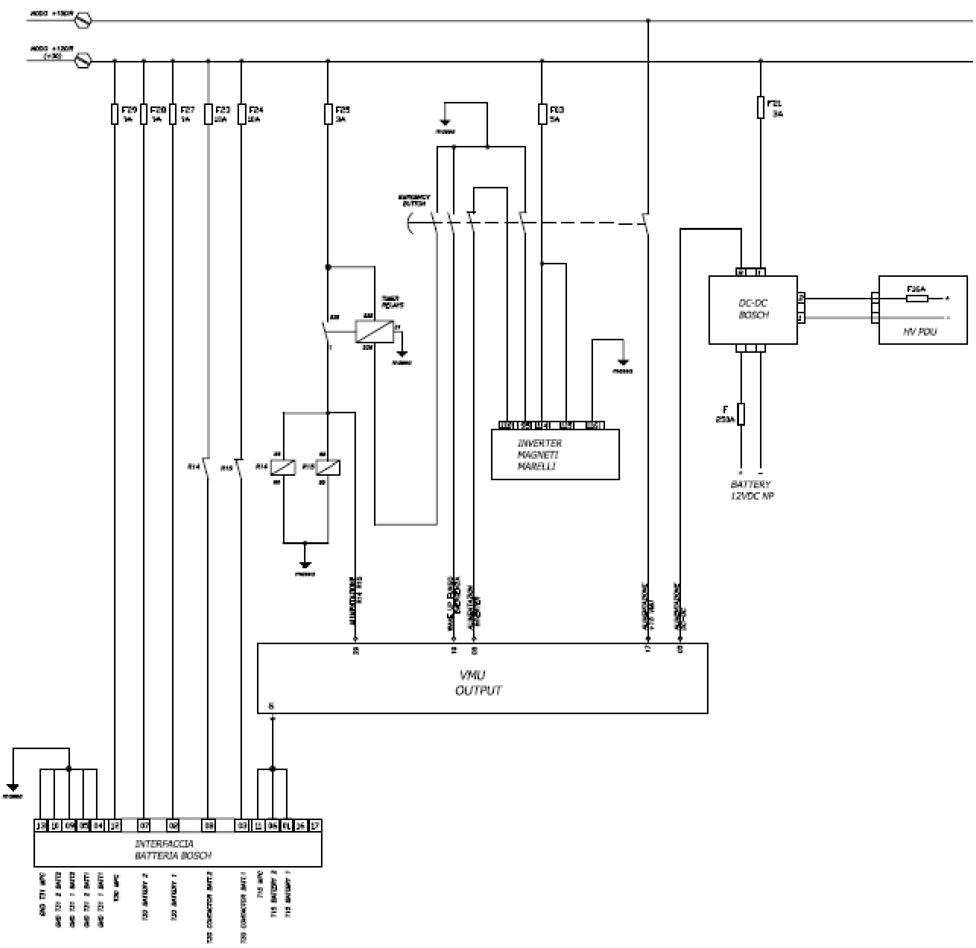


**Figure 2-5 HV Emergency Shut Down Circuit**

## 2.3 Cooling System Integration

As said in the previous chapter 2.1, the cooling circuits design has been modified with respect to what defined in the last Deliverable D5.2. In fact, after the preliminary test on the vehicle, we introduced an additional third loop, in order to guarantee the HV battery system right operating temperature in all possible operative conditions. While, according the Bosch indication, the HV batteries should have been able to work correctly at the temperatures guaranteed by the cooling circuit first implementation, in order to prevent risks and being forced to change the circuits during the assessment phase, IVECO team decided to apply the modification described in the pictures below:

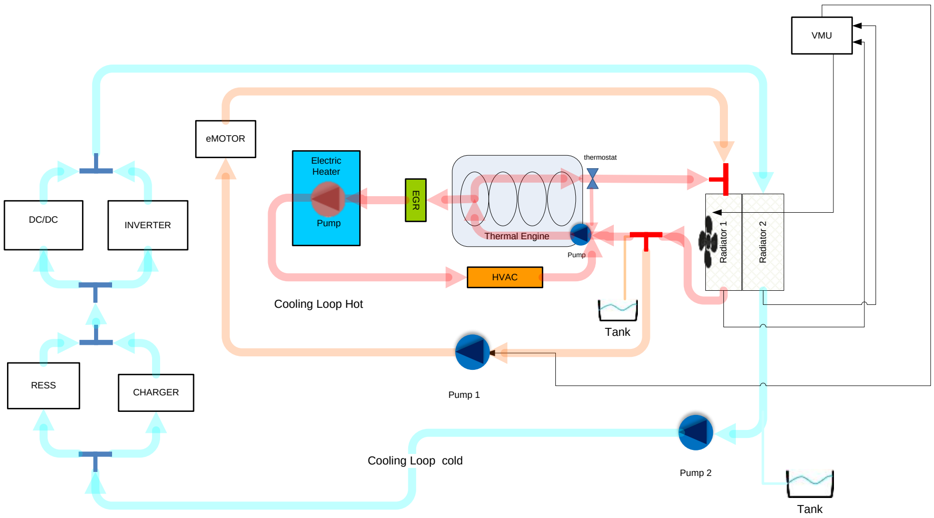


Figure 2-6 Hybrid components previous Cooling Circuit

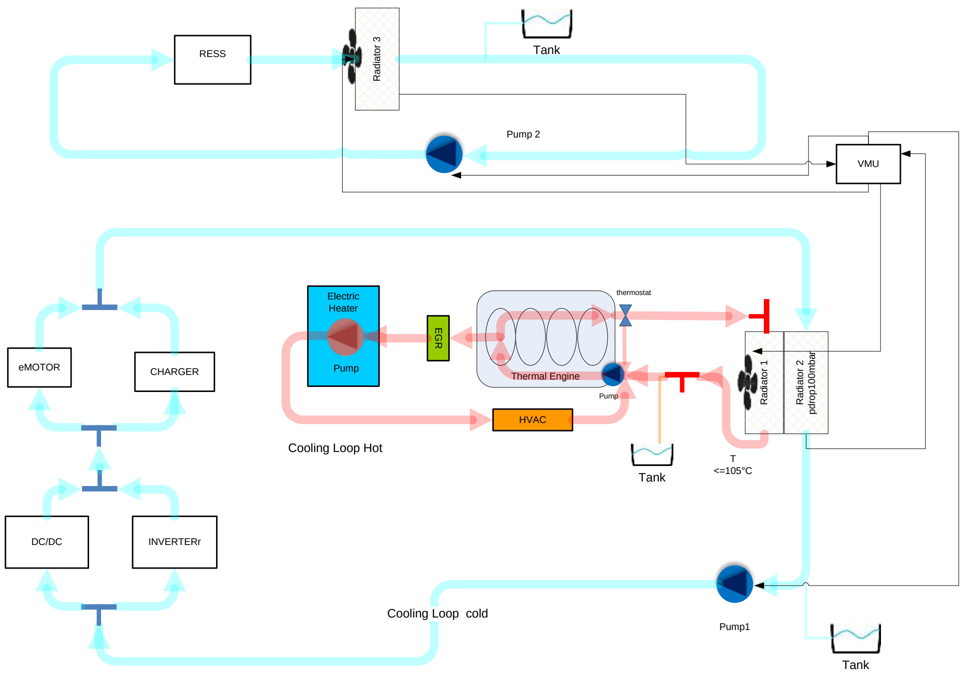


Figure 2-7 Hybrid components new Cooling Circuit

The pictures below show the installation of the three radiators.

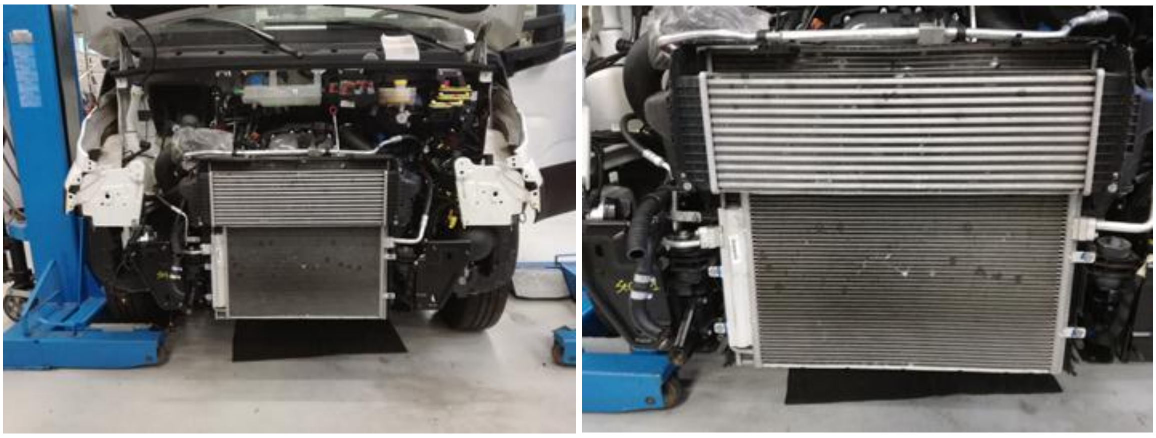

**Figure 2-8 Radiators for Electric Drive and Diesel Engine**

**Figure 2-9 Radiator for HV Batteries**

## 2.4 Cabin Components Integration

### 2.4.1 HMI Components

Among the main new components installed on the demonstrator, there are the HMI devices:

- The Tablet (TOMTOM) and its Cradle
- The  Bluetooth Gateway

**Figure 2-10 HMI Installation Step 1-2**

**Figure 2-11 HMI Installation Step 3 (Cradle) – Step 4 (TOM-TOM)**

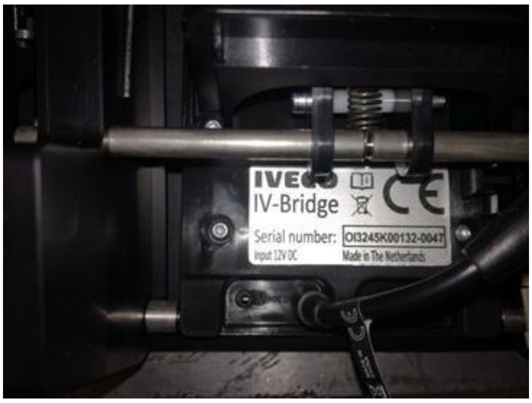


**Figure 2-12 CAN-Gateway BT**

As already described in the previous deliverable D5.2, the System Schematic block diagram is:

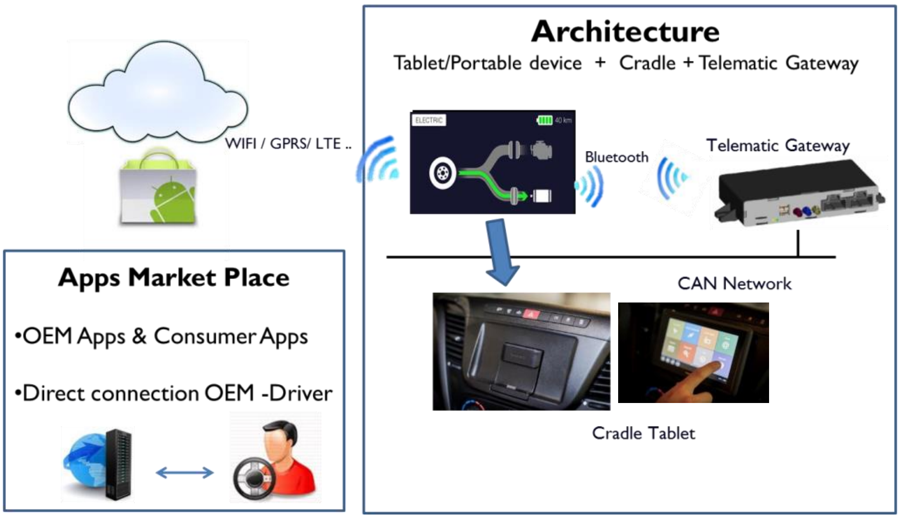


**Figure 2-13 HMI Schematic Diagram**

### 2.4.2 Hand Lever interface

In order to provide the easiest way to manage the "Mode Switching", it has been developed a customized hand lever that integrates specific HW and SW features. Considering also a specific modification implemented on the Gear Box shifting command, the hand lever provides an additional position that allows the driver to select the Electric mode.

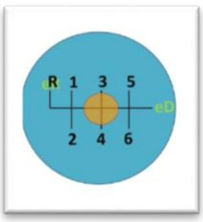


**Figure 2-14 Hand Lever Positions including ED Electric mode**

IVECO target was to not integrate any additional buttons, on the dashboard, for the Hybrid Traction Management, because all the functionalities related to the traction should be controlled by the Hand Lever.

**Figure 2-15 Hand Lever Installation**

## 2.5 Charging Components Integration

As Described in the Deliverable D5.2, the IVECO customers are asking to have a vehicle interoperable with any AC batteries charging infrastructure.

A specific IVECO patented system has been implemented in order to satisfy the requirements and to keep the flexibility of Mode 1 with CEE type connection, Mode 3 public charging capability with type 2 connectors and the home-charging (for restricted condition/recovery, one phase low power).

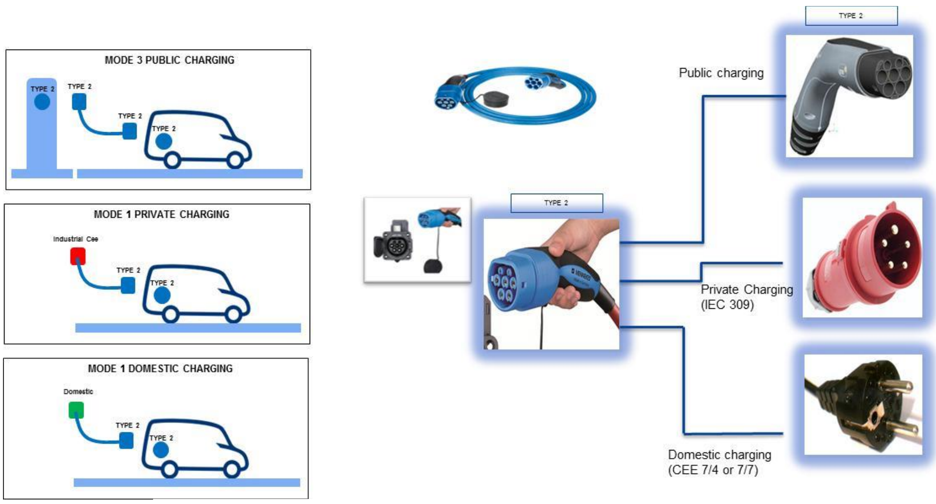


**Figure 2-16 Charging System Description**

**Figure 2-17 Charging system, cable assembly, vehicle inlet (Type 2) and Mode3 charging set**

## 3 Vehicle Start-Up and First Calibration

The subtask 5.3.1 was dedicated to developed and verify, through preliminary functional test sessions, the control algorithms for the traction system.

Software for handling algorithms has been developed based on three guidelines: functional specifications, safety strategies & requirements and HMI application.

The control functions have been implemented on the Vehicle Management Unit (VMU).

Furthermore, the aim of the Subtask 5.3.2 was the energy management algorithms development for a plug-in hybrid vehicle energy generation optimizing strategy, distribution, utilization and storage. The activity was also oriented on finding methodologies aimed to integrate and share energy from mechanic, electric and thermal domain.

The energy management platform includes also the auxiliaries control, in term of power smart management, flexible heating/cooling systems and power steering activation and supervision in the different manoeuvres.

Finally, in order to enlarge the hybrid vehicle overall efficiency, the strategies to optimize the energy storage during charging and discharging and the smart grid control (that represent a significant area of competiveness) have been developed.

### 3.1 Electrical and Mechanical Tests and Checks

In order to avoid Electrical and Mechanical problems on HV and LV components, some checks have been performed during the vehicle Start-Up by BOSCH , FPT and IVECO teams.

The table below shows some of the most important test performed on the HV and LV Components:

| Type of test | Description/Impacts |
|---|---|
| **Visual Inspection of wiring and connectors** | Avoiding moisture in the area of the installation location (drain valve, drain possibility, ...), Visible defects in HV and / or LV connectors, visible missing and / or defect insulation of the cables, etc. |
| **Visual mechanical Inspection** | Check of the Brackets and fixation points. No parts installed which can mechanically penetrate into the component housing in the event of a crash. (especially critical for HV Battery) |
| **Visual Inspection** | No direct heat source > 120 ° C with direct or indirect thermal connection to the battery system and HV System |
| **Electrical Inspection** | Ground connection and equipotential connections on vehicle side verification and check; proper polarity connections check |
| **Electric Line Protection** | HV power line and LV power line proper fuse and coordinated protection check |
| **Grounding and supply concept** | Proper (< 40 mOhm) grounding connection check with at least 200 mA. |
| **CAN Bus lines** | Proper connection check and termination resistance verification |
| **LV and HV Pin assignment** | LV and HV pin out check |
| **HV-Interlock line(s)** | Check wiring of the component in the Interlock loop |

| Type of test | Description/Impacts |
|---|---|
| **Isolation measurement without battery (vehicle side)** | HV+ and minus versus chassis equipotential reference => >2.5 MΩ (500 Ohm/V required) |
| **Emergency Shut Down with battery** | Check functionality : power supply shall be cut off, HV systems de energized |
| **Manual Service Disconnect (Battery Pack)** | Visual inspection; each switch on the battery packs tested |
| **System Startup**<br>**System Shutdown** | Checked start up and shutdown timing and verified NO errors ( Can messages) |
| **Test for absence of harmful voltages with HV Battery open contactors** | Check of Pack Voltage : HV+ against HV- below 60 V after 10 s |
| **Isolation measurement with open contactors** | HV+ against GND => Tolerance: >2.5 MΩ (required 500 Ohm/V) |
| **Measurement of RESS parameters with closed contactors** | Check Battery packs Values (Voltage, SoC etc .). |
| **Isolation measurement with closed contactors** | HV+ against GND => Tolerance: >2.5 MΩ (required 500 Ohm/V) |

## 3.2 Functional Tests and Checks

Once performed the preliminary electrical and mechanical tests, the teams performed other list of checks.

The following table shows some of the most important functional test performed on the HV and LV Components:

| Type of test | Description/Impacts |
|---|---|
| **Flashing SW** | Check Flashing procedure for all the Control Units |
| **System Startup**<br>**System Shutdown** | Check the right sequences of Power up and Power off on the HV and LV components in normal operating conditions. |
| **Diagnostic identification** | After start up, each system has to be able to perform self-diagnosis and provide fault codes if present via CAN messages or warning lamps |
| **Main Contactor Control** | Check if the Vehicle Management Unit (VMU) is able to control the Battery main contactors |
| **Isolation monitoring** | Check if the monitoring is performed correctly while Driving, while Stopped and while Charging |
| **Interlock functionality** | Check if the functionality is performed correctly while Driving, while Stopped and while Charging |
| **CAN breakdown** | Check ECU behaviours after a Can Breakdown |

| Type of test | Description/Impacts |
|---|---|
| **12V supply breakdown** | Check ECU behaviour after 12V supply breakdown |
| **Emergency shutdown button** | Check ECU behaviour after using the Emergency Button |
| **Manual Service Disconnect (on Battery pack)** | Check ECU behaviour of the vehicle system after using the MSD |
| **Battery Charging** | Check if the all the ECUs and components involved work well while the Vehicle Management Unit (VMU) is controlling the battery system for charging procedure (Mode3 and Mode1) |
| **Battery Discharging** | Check if all the ECUs and components involved work well while the Vehicle Management Unit (VMU) is controlling the vehicle in Hybrid mode and Electric mode |
| **DC/DC functionality** | Check the correct behaviour of DCDC (Output current and voltage) while VMU is setting a target voltage > actual voltage |
| **Cooling functionality** | Check if all the cooling components have a proper thermal behaviour while the Vehicle Management Unit (VMU) is managing the vehicle in Hybrid mode, Electric mode, Diesel mode and while charging. |

#### 3.2.1 Test and Log in Pure Electric Mode

Confidential content

#### 3.2.2 Test and Log in Hybrid Mode

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#### 3.2.3 Test and Log in Diesel Mode

Confidential content.

#### 3.2.4 Test and Log in Charging Mode

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# 4 Conclusions

The task 5.3 had the main target to build up the Demonstrator and to perform the start-up.

Together with BOSCH and FPT, Iveco/Altra team were able to test all the main vehicle functions and to formalize that the first SW version of the various control units are working correctly.

- Final Powertrain Mass and Payload are in line with the targets
- All the functioning modes are working properly
- Electrical and mechanical test didn't find out any issues or design Inconsistencies.

Of course these SW versions are only a first stage, that make the WP5 team able to start the task 5.4 "Testing and Fine Tuning of the demo vehicle" with a good level of confidence that the final targets could be reached without problems.

# 5 References

*This project has received funding from the European Union's Horizon research and innovation programme under grant agreement no 653468*

## Appendix B – Abbreviations / Nomenclature

| Symbol / Shortname | |
|---|---|
| **ABS** | Anti-lock Braking System |
| **ASR** | Automatic Skid Reduction |
| **BEV** | Battery Electric Vehicle |
| **BMS** | Battery Management System |
| **CAN** | Controller Area Network |
| **EBD** | Electronic Brakeforce Distribution |
| **ECU** | Electronic Control Unit |
| **EDC** | Engine control Unit |
| **EHPS** | Electrohydraulic Power Steering |
| **EMG** | Electric Motor Generator |
| **EOL** | End Of Life |
| **EPB** | Electric Parking Brake |
| **EPS** | Electric Power Steering |
| **ESS** | Energy Storage System |
| **ESP9** | Electronic Stability Program |
| **EU** | European Union |
| **GVW** | Gross Vehicle Weight |
| **HVPD** | High Voltage Power Distribution |
| **HMI** | Human Machine Interface |
| **HVAC** | Heating Ventilation Air Conditioning |
| **MSD** | Manual Service Disconnection |
| **OEM** | Vehicle Manufacturer |
| **PCM** | Power control module |
| **PHEV** | Plugin Hybrid Electric Vehicle |
| **PM** | Permanent Magnets |
| **PTO** | Power take off |
| **RCCB** | Residual current circuit breaker |
| **SOC** | State of charge |
| **Std.** | Standard |
| **VMU** | Vehicle management unit |
| **VRU** | Vulnerable Road Users |