Rare Earth Free e-Drives Featuring Low Cost Manufacturing

Collaborative Project
Grant Agreement Number 770143

Start date of the project: 1st October 2017, Duration: 42 months

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770143

Work Package no.: 7
Title of the WP: Powertrain Testing, Vehicle integration and Validation
Deliverable no.: 7.3
Title of the deliverable: In-vehicle Technology Validation

Contractual Date of Delivery:	**31/03/2021**
Actual Date of Delivery:	**24/05/2021**
Lead contractor for this deliverable:	**PRI**
Author(s):	**Walter Vinciotti (PRI), Paolo Pipponzi (PRI), Simone Giansanti (PRI)**
Participants(s):	**Alicia Rodriguez (CID), Javier Romo (CID)**
Work package contributing to the deliverable:	**WP7**
Nature:	**Report (Public)**
Version:	**6.0**

REVISION TABLE		
Document version	**Date**	***Modified sections - Details***
V1.0	26.03.2021	Draft Outline
V2.0	28.03.2021	Section 4 and 5 updated
V3.0	31.03.2021	CIDAUT contributions
V4.0	31.03.2021	Draft version
V5.0	31.03.2021	Review version
V6.0	21.05.2021	Final version

Table of Contents

Abbreviations

ABS: Anti-lock Brake System
AC: Alternative Current
BMS: Battery Management System
BOM: Bill Of Material
BP: Battery Pack
CAN: Controller Area Network
CC: Cooling Circuit
DC/DC: DC converter
DC: Direct Current
HMI: Human Machine Interface
HV: High Voltage
ICE: Internal Combustion Engine
IM: Induction Motor
IMD: Insulation Monitoring Device
LV: Low Voltage
PB: Power Braking
PM: Permanent Magnet
PS: Power Steering
PWM: Pulse-Width Modulation
SOC: State Of Charge
Synrel: Synchronous reluctance
VCU: Vehicle Control Unit
WLTP: Worldwide harmonized Light vehicles Test Procedure
WP: Work Package

1 Executive Summary

This document is a description of the activities that have been carried out on the Mercedes Sprinter demonstrator after the end of work package (WP) 5. The purpose of the WP7 – Task 7.3 is to electrify the van to integrate the powertrain into the vehicle, bench testing of the powertrain components, testing the motors on the vehicle on the road. For simplicity, we have divided it into three main areas.

1. Integration:

   This task is the set of activities (disassembly, new supports, new connections, new wiring, etc.) to electrify the van, based on the projects and guidelines already defined in deliverables 5.4 and 5.5. In particular, these activities had as main focus the realization of the high (HV) and low voltage (LV) wiring, the safety of the prototype and a motor installation system in the vehicle that ensures correct operation and also make it easier to exchange the drivetrain.

2. Test at component level:

   Privé, before and during the integration, tested the battery and the main components of the vehicle in stand-alone conditions or on a test bench custom-designed for such activities. This allowed for faster debugging on the vehicle and reduced the risk of component failure.

3. Test at vehicle level:

   This phase has been performed in two parts. The first had as main concern the debugging of the vehicle parameters and the optimization of the communication between all the components. In the second part, the final tests were carried out aimed at acquiring the data that were used for the characterization of the motors and the electronics.

The task initially scheduled from month 25 to month 36 of the project, due to delays in the previous WPs owing to Covid-19, has been extended by 6 months.

The task involved testing the 4 motors of 75 kW produced in the project (Induction Motor (IM) die-cast, IM fabricated, Permanent Magnet (PM) assisted and Pure Synchronous reluctance (Synrel) motor) due to the delays already mentioned and unexpected issues it was possible to test only one motor, the pure Synrel.

The testing of the pure Synrel motor aboard the electrified Mercedes-Benz Sprinter was successfully performed. The tests gave good driving sensations at low speeds, thanks to the good torque of the e-motor. However, the maximum speed reached by the vehicle/motor and the cooling system performance are lower than the expected ones.

2 Component Integration

2.1 Battery pack

In the deliverables 5.4 and 5.5, we had defined the design of the battery and started the manufacturing process according to our production drawing. In Fig. 1 it is possible to see a rendering of the battery pack (BP) with the 7 modules connected by 6 steel bars, the cooling circuit (CC) in blue and the power connectors on the left side of the housing.

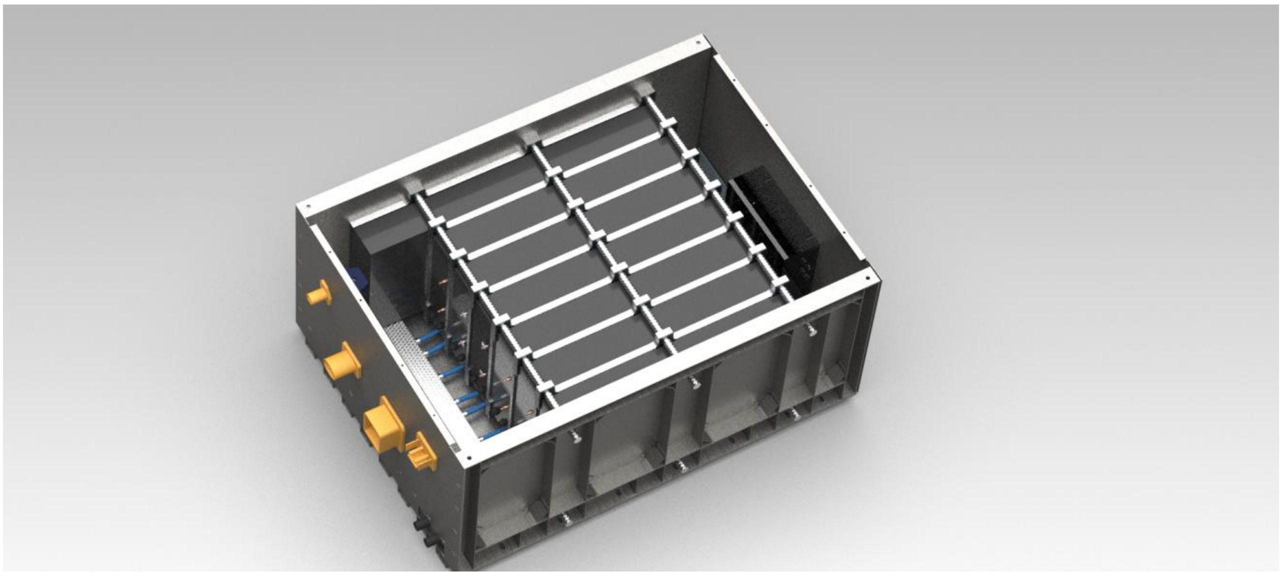

Fig.1 final rendering of the BP

The manufacturing and assembly process has been supported by six main suppliers, each of them has carried out specific tasks listed below supported by our engineering team:

- Aluminium cooling plates production
- Modules and battery management system (BMS) production, sub-assembly and test
- Wiring harness setup
- Cooling system installation on the vehicle and sub-component production (liquid tank, in and out manifold)
- Steel frame production
- Battery assembly and integration on the vehicle

The final component can be seen in Fig. 2 installed in the rear part of the sprinter to keep the centre of the mass low and to minimize the polar moment of inertia of the vehicle.

Fig.2 BP installed in the vehicle and HV routing

2.2 E-motor and Inverter

The electric motor and inverter were installed on the vehicle with a specific steel frame designed by our engineers for the ReFreeDrive purpose. As already specified in D5.4 and D5.5 this activity started with a 3D scan of the van's underbody after the internal combustion engine (ICE) was removed.

The chassis was positioned on 3 supports, considering X the vehicle's advancement axis and Y its transverse axis:

- 2 supports at the same value of the X-axis and with a symmetrical position with respect to the Y-axis, using the rear engine supports with anti-vibration dumpers. They have been designed to lock the Z displacement of the frame and rotation in the YZ plane.

- The third has been positioned further back on the X-axis, on the fixing that was initially of the rear part of the gearbox in the original configuration. This fixing is of the hinged type and has been equipped with an anti-vibration dumper that blocks displacements in X and Y.

In Fig.3 and Fig.4, it is possible to see the e-motor mounted and part of the frame that wraps the right side of the reduction box.

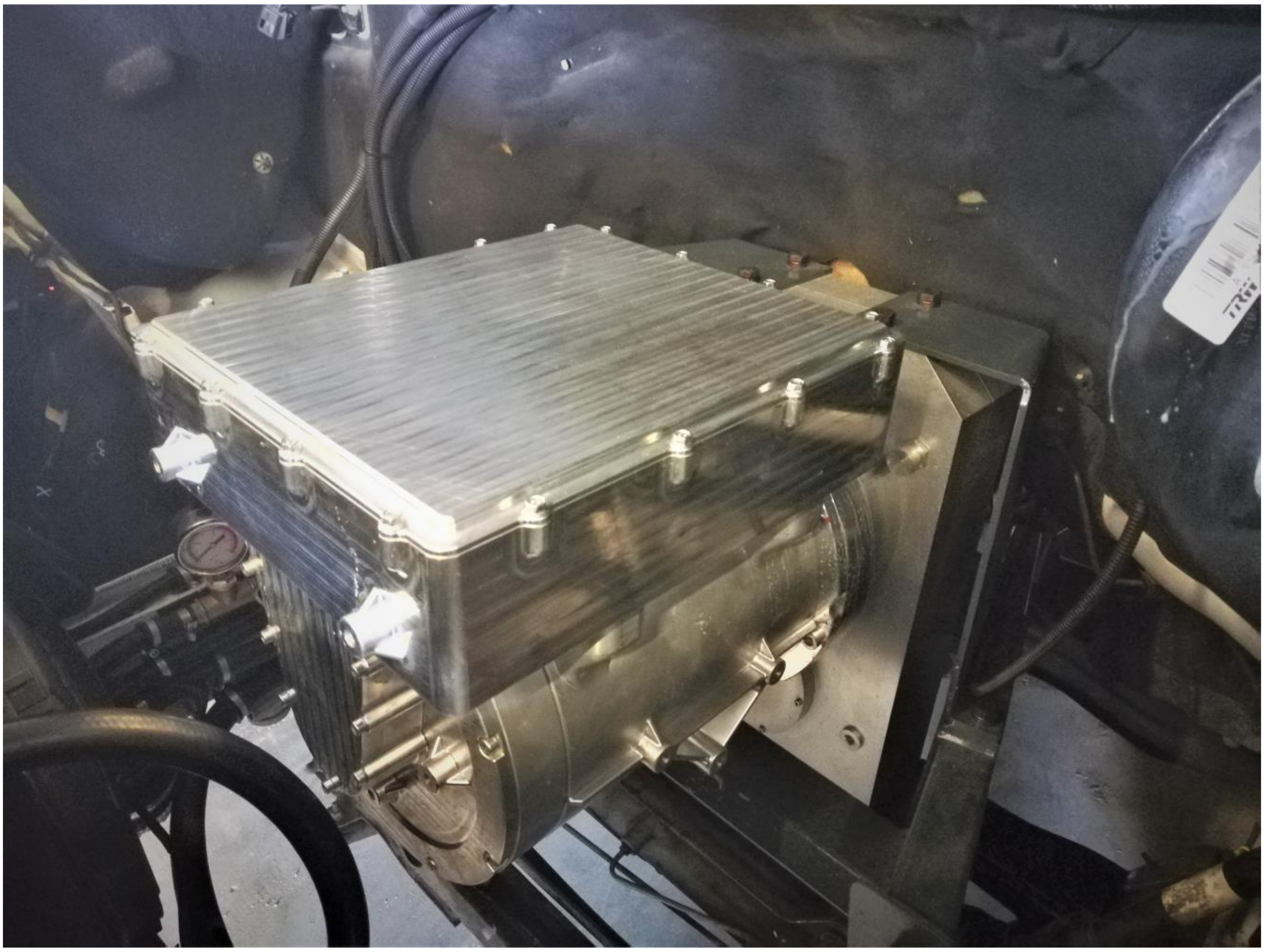

Fig.3 Motor and inverter assembled on the reduction gearbox and side view of the frame

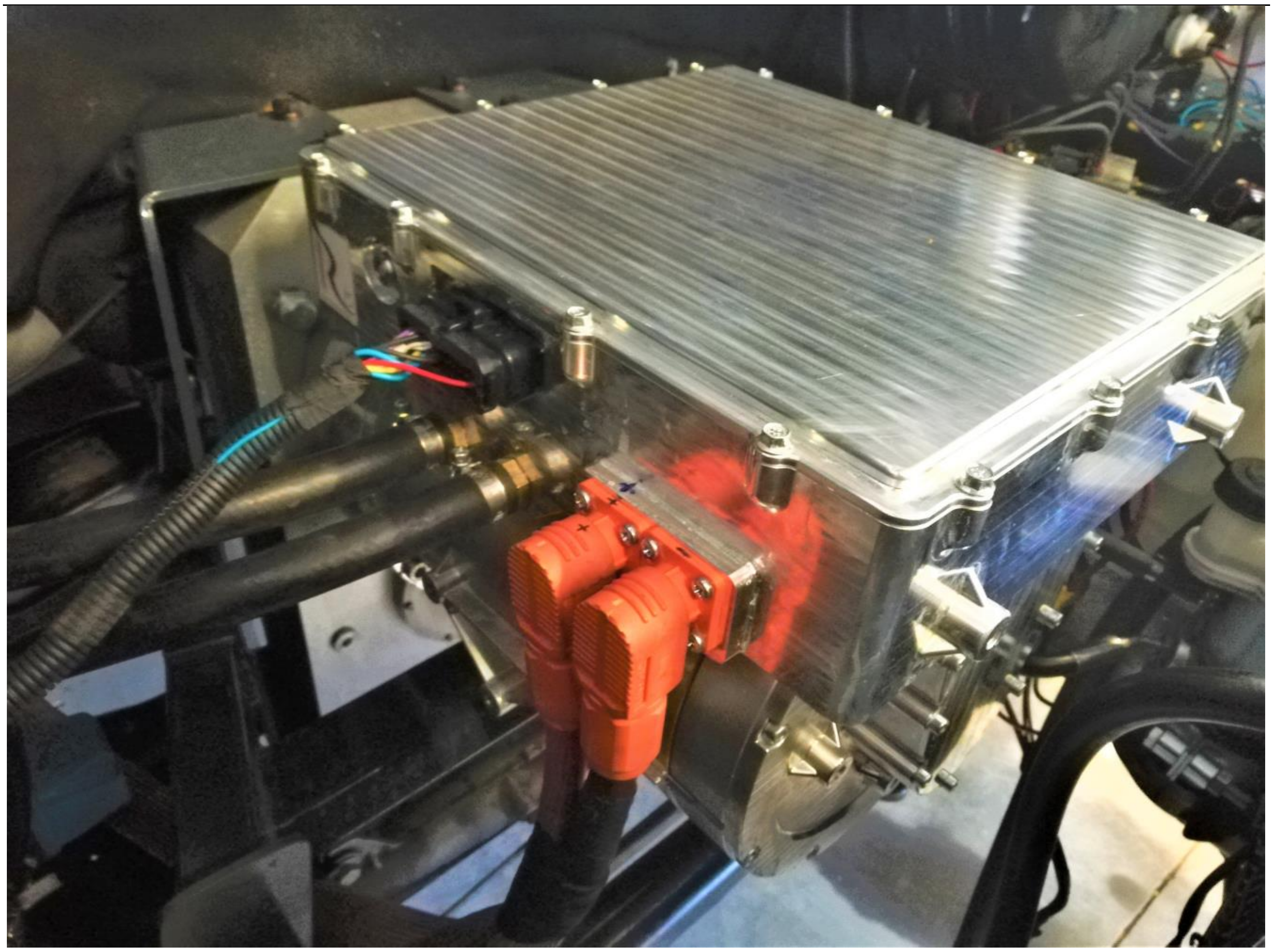

Fig.4 View of the inverter with the power connector, CC and motor support frame

2.3 Electrical Routing and sub-components

The electrical routing manufacturing and installation has been one of the main tasks carried out during the final integration phase.

The HV wiring connects the alternative current (AC) inlet – Charger – battery box – direct current (DC) converter (DC/DC) – Inverter – Motor. The AC inlet has been installed on the left side of the vehicle replacing the original fuel inlet. In Fig.5 is shown the HV internal battery wiring and in Fig.6 we can find a view of the power connections between charger, DC/DC and BP.

A new controller area network (CAN) line has been developed and realized to ensure safe and stable communication between components. The components connected are BMS, Inverter, vehicle control unit (VCU) 1, VCU 2, human machine interface (HMI), DC/DC and charger. Can Line baud rate is 500 kbit/s and the status data are published by the components every 100ms, compliant with automotive standards. The main aims of the new CAN line are:

- Managing the basic functionalities of the vehicle such as braking pump (PB), steering pump (PS), Anti-lock Brake System (ABS), lights and so on.
- Putting in communication the BP with the inverter and the charger to ensure the safety of the system and the required performances in a different mode of operation of the vehicle such as charging, drive mode, power derating or faults.
- Ensuring the correct functioning of the HMI and data collecting for testing purposes.

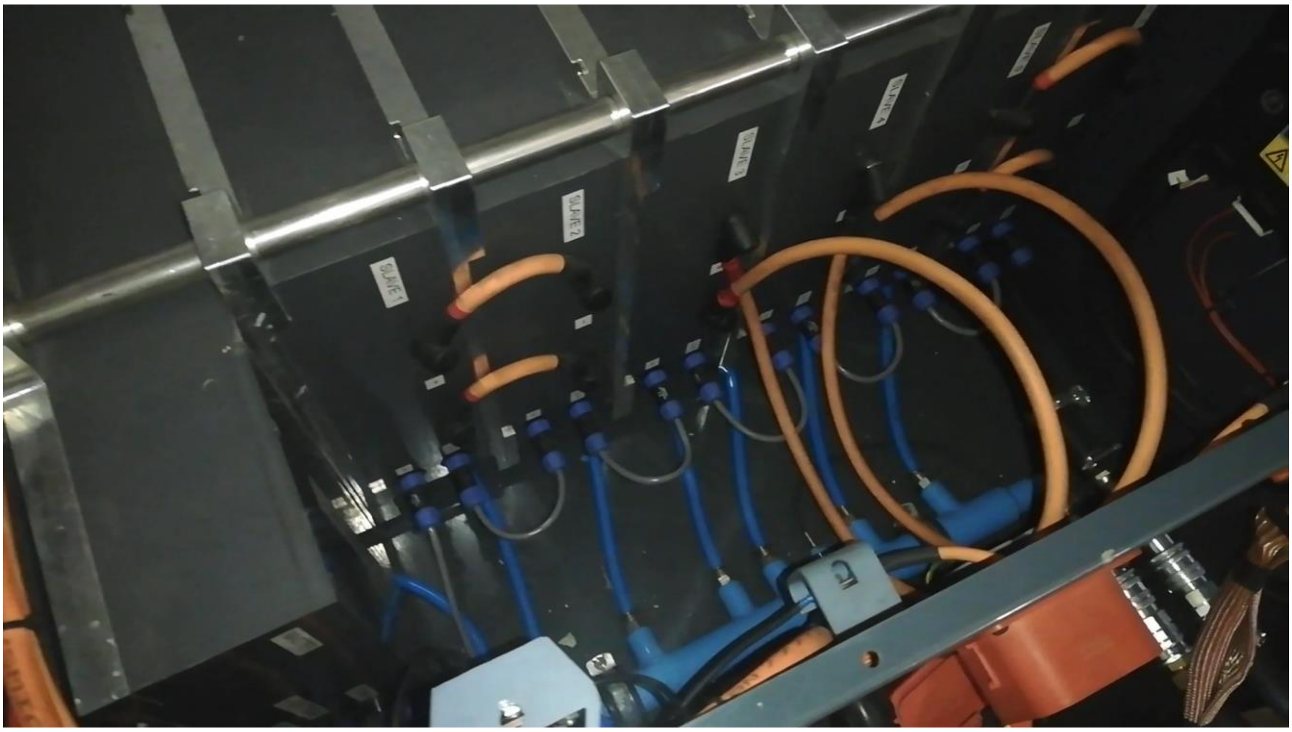

Fig. 5 View of the HV wiring inside the battery box

Fig. 6 View of the HV wiring harness

2.4 Charger

The charger has been installed in the back of the vehicle in proximity to the BP and the DC/DC to keep the routing short and organized. On the left side of the charger (Fig. 6), it is possible to see the AC input and the CC inlet and outlet. On the right side, we can see the direct current (DC) output that goes directly into the BP through a specific connector.

The CC of the charger is the same as the motor, or better, they share the main components: water pump, tank and radiator. There is a 3-way valve to select the direction because the motor and the charger always work alternately.

The component has been connected directly to the chassis of the Mercedes Sprinter using custom made steel plates, as seen in Fig. 7.

Fig. 7 Connection of the charger with the Sprinter chassis

2.5 Drive Train

The custom-made drive train as designed in D5.4 and D5.5 has the function of replacing the gearbox of the engine propelled vehicle ensuring the correct reduction ratio at the wheels. This group is made of 2 main parts:

- Reduction box (with two parallel shafts and opposite input and output has the function of reducing the rpm of the e-motor and aligning the output with the transmission shaft).
- Transmission shaft (made of 2 main shafts connected with specific homokinetic joints has been manufactured to connect the reduction box to the differential of the vehicle on the rear axle).

The reduction box is connected to the chassis by the motor support frame and through a front flange visible in Fig. 8, they guarantee a structural connection with the e-motor stator. At the centre of the flange in Fig. 8, it is possible to see the input shaft that has been connected through a dedicated spline with the shaft of the e-motor.

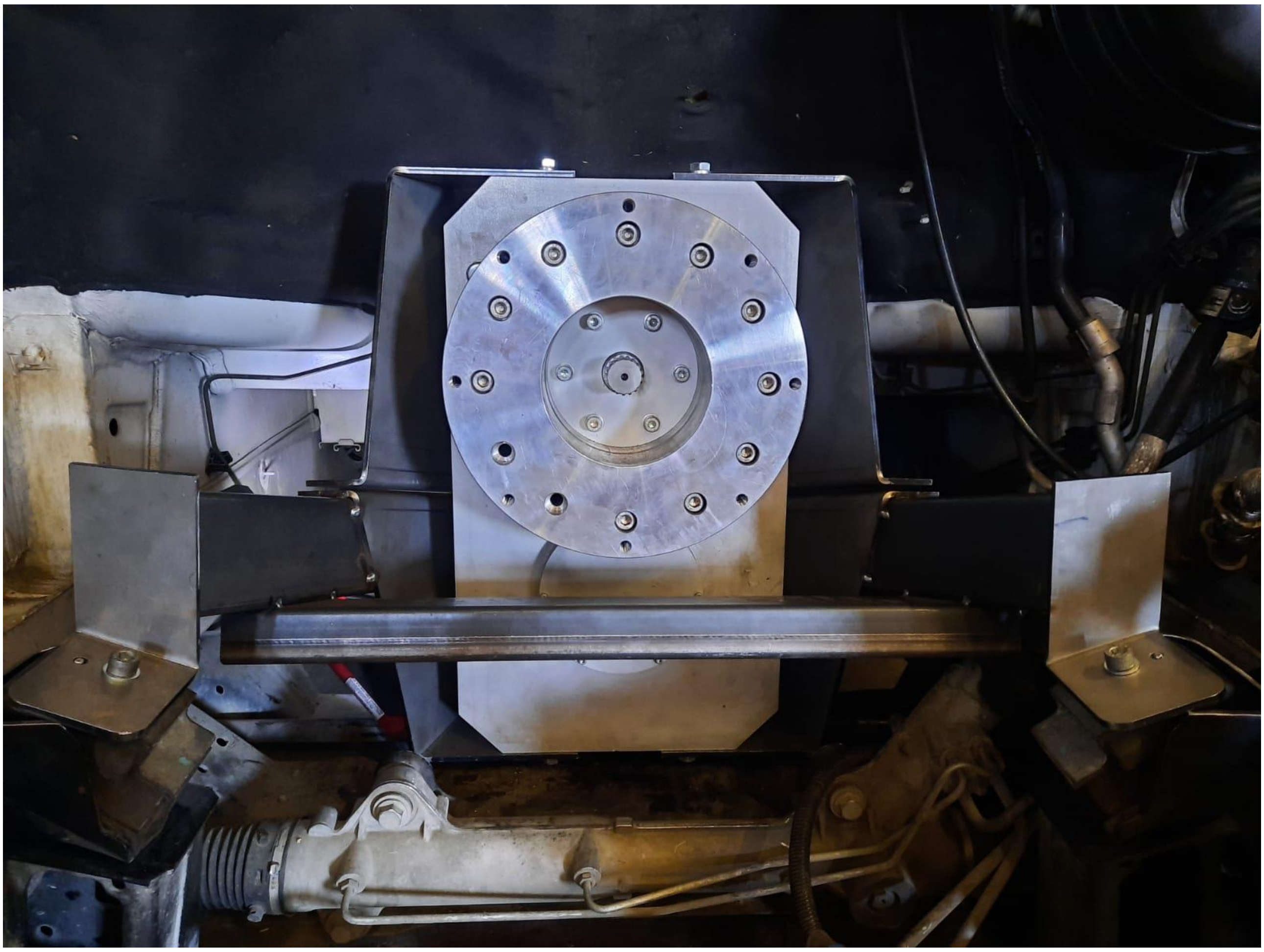

Fig. 8 A frontal view of Reduction box

2.6 HMI

The HMI system is made of hardware (10.1 Inch Double Din Android 8.1.0) and custom made software based on the TORQUE platform. The system communicates with the CAN line of the vehicle and it can provide information related to the performances (speed, rpm, current) the power consumptions, the status of the battery, and so on.

Below the touch screen, as shown in Fig. 9, we can find 4 buttons that have the following functions:

- the first button or red button is used to engage reverse gear with a percentage torque of 65% of the maximum torque (176Nm)
- the 2nd button or blue button is the "neutral" position (engine running but traction not enabled)
- the 3rd and 4th buttons or green buttons enable 2 different traction modes: one with 80% torque (ECO) and the other with the full torque available (SPORT)

The starting procedure is realized using the original Mercedes key-block by a modification of the original signals, and works as follow on key turns:

- first key position: HMI switch on,
- second key position: switch on all the main devices,
- third key position: hold-on position for 1 second + brake pedal push put the vehicle in “ready to run” neutral mode,
- If the recharge Mennekes “gun” is plugged in the vehicle, the system does not allow the run mode,
- Once the vehicle is on the “ready to run” neutral mode, the drive mode can be enabled with brake pedal push + red or green button.
- 

Fig. 9 HMI and buttons

2.7 Services

The vehicle base functions have been restored using two VCUs programmed by our team of engineers with the functions described in D5.4 and D5.5. To have the correct integration between our VCUs and the original vehicle system, we have designed two further electrical boards that control the fans and the cooling water pumps in pulse-width modulation (PWM).

Two separated CCs have been designed (one for the BP and one alternately for the drivetrain or the charger) and equipped with two radiators designed and manufactured for the purpose and installed in the front part of the vehicle to be exposed to the airflow.

The original ICE vehicle had a PS connected with a belt to the flywheel: the electric van has been equipped with a new electric PS powered by the 12 V system, as shown in Fig.10.

The original 12V battery has been replaced by a lithium one that can provide up to 40amps and is managed by its own BMS. The new 12V battery is recharged by the DC/DC directly managed by the CAN line, it gets the power from the HV battery and it is air-cooled with two fans.

In order to provide the safety of the system, when the battery is completely charged and there is an overflow of current due to vehicle braking, we implemented a resistor of 1800W inside the front trunk that has the function to dissipate the power that is not possible to regenerate.

Fig. 10 View of the PB, PS and fuses box

3 Tests at components level

The testing phase at the components level has been carried out before and during the integration process to ensure the correct level of safety. A specific test bench has been created in our workshop as shown in Fig. 11, Fig. 12 and Fig. 13. The following parts and subsystems have been tested:

- components of the electric powertrain
- communication system
- BP liquid cooling system
- HV and LV routing

The main goals of the tests carried out were:

- Debugging of the communication hardware between, VCU 1, insulation monitoring device (IMD), VCU 2, BMS, Charger, DC/DC and the related custom protocol
- Design, assembly and testing of the Low Voltage and High Voltage routing
- Mechanical check of the Battery CC
- Debugging of the charging and discharging phases of the battery using the test bench resistors, shown in Fig 14
- Set up of the State of Charge (SOC) of the BP and tuning of the BMS functions
- Set up of the liquid cooling pump and coolant flow

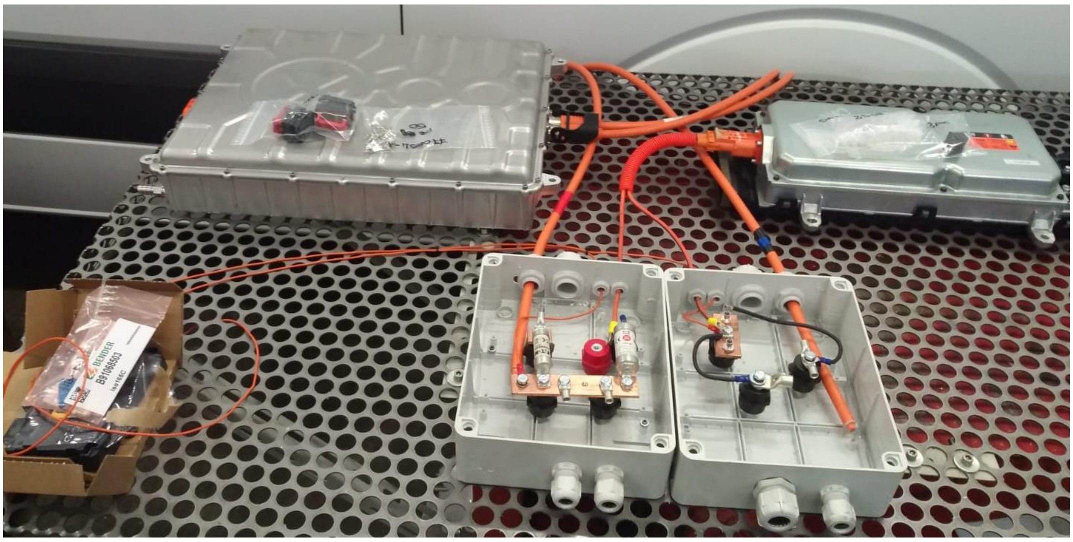

Fig. 11 Test bench with charger, DC/DC, power distribution box

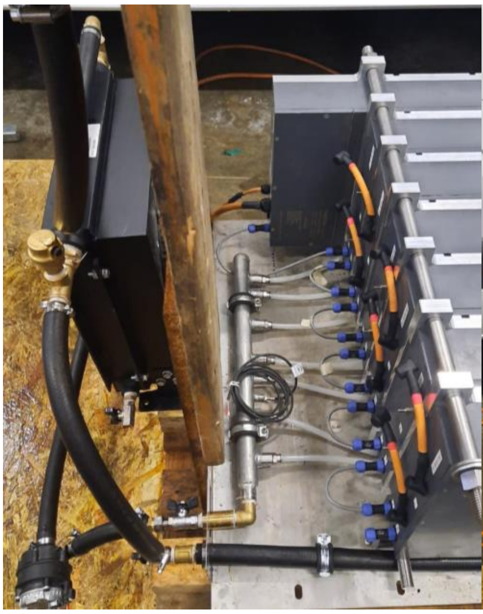

Fig. 12 The CC of the BP with manifold and modules inlet

Fig. 13 The test bench with the CC of the BP, radiator, tank and pump

Fig. 14 The resistors test bench to test the discharge of the BP, 5 resistors of 2kw each and 100 Ohm

The outputs of this activity have been the following:

- The final release of the VCU software
- The final release of the BMS firmware
- LV and HV wiring final bill of material (BOM) and assembly sequence.
- Tuning of the hydraulic circuit

4 Tests at the vehicle level

4.1 Test Plan

To evaluate the performance of the powertrain developed in the project the following testing plan has been programmed (Table 1).

It is important to highlight in this section that due to the delay in the project accumulated at several levels and stages due to the Covid-19 pandemic it was possible to carry out those tests just on one of the e-motors and inverters: Pure Synrel.

Table 1: Test plan

Name of Test	Description of Test	Goal of Test
Visual check	Visual inspection of the connectors and liquid cooling system	Safety check
Insulation	Check of the frame insulation	Safety check
Run mode	The test consists of activating the run mode and then activate the forward mode, drive few meters, activate the reverse mode, drive again a few meters backwards and repeat the procedure	Safety check
Drive mode selector	Push buttons to select the different drive modes and check the functions (Rear, ECO, Sport, Neutral)	Safety check
Brick	Pass the step of 15 cm, repeated five times in forward and five backward.	Evaluate the max torque and current of the system
Acceleration	Turn on, measure the time of 0-60km/h and check the derating. Must be repeated 3 times	Evaluate the performance of the vehicle and the efficiency of the system at high torque, high current
Max speed	Turn on 0-MaxSpeed and check the derating. Must be repeated 3 times	Evaluate the performance of the vehicle and the efficiency of the system at high power, high rpm
WLTP Worldwide harmonized Light vehicles Test Procedure	Run the WLTP as much as possible near the theoretical one and check thermal, electrical and mechanical performances	Evaluate the performance of the system and the powertrain in a standard driving cycle
Test at constant speed	Turn on and bring the vehicle at the requested speed and keep the speed for at least 10 s	Evaluate the efficiency of the system at different speed and torque level
v= 20 km/h		
v= 35 km/h		
v= 50 km/h		

For each test the following variables have been gathered using the CAN line and our data logging system:

- Motor rpm
- Inverter currents and voltages
- Battery voltage, current, SOC and temperatures
- Inverter temperatures
- Motor temperatures
- Liquid coolant temperature and pressure

Motor power and torque values are calculated by the inverter functions based on the tests carried out by IFPEN.

4.2 Test Results

4.2.1 Brick Test

Test target:

This test evaluates the behaviour of the motor forced to deliver a high torque necessary to overcome the obstacle with the rotor almost blocked.

Boundary conditions:

The ambient temperature is about 25°C. The SoC of the battery pack is 100%.

Test Procedure:

1. The van is positioned in front of the 15 cm step to be overcome, with the front wheels resting on it.
2. The acceleration pedal is pressed for its entire strike (100%).

Exemptions:

None

Results and comments:

The test was successful, in Fig. 15 and Fig. 16, it is possible to see the maximum torque that the motor has been able to provide and the slight increase in motor temperatures

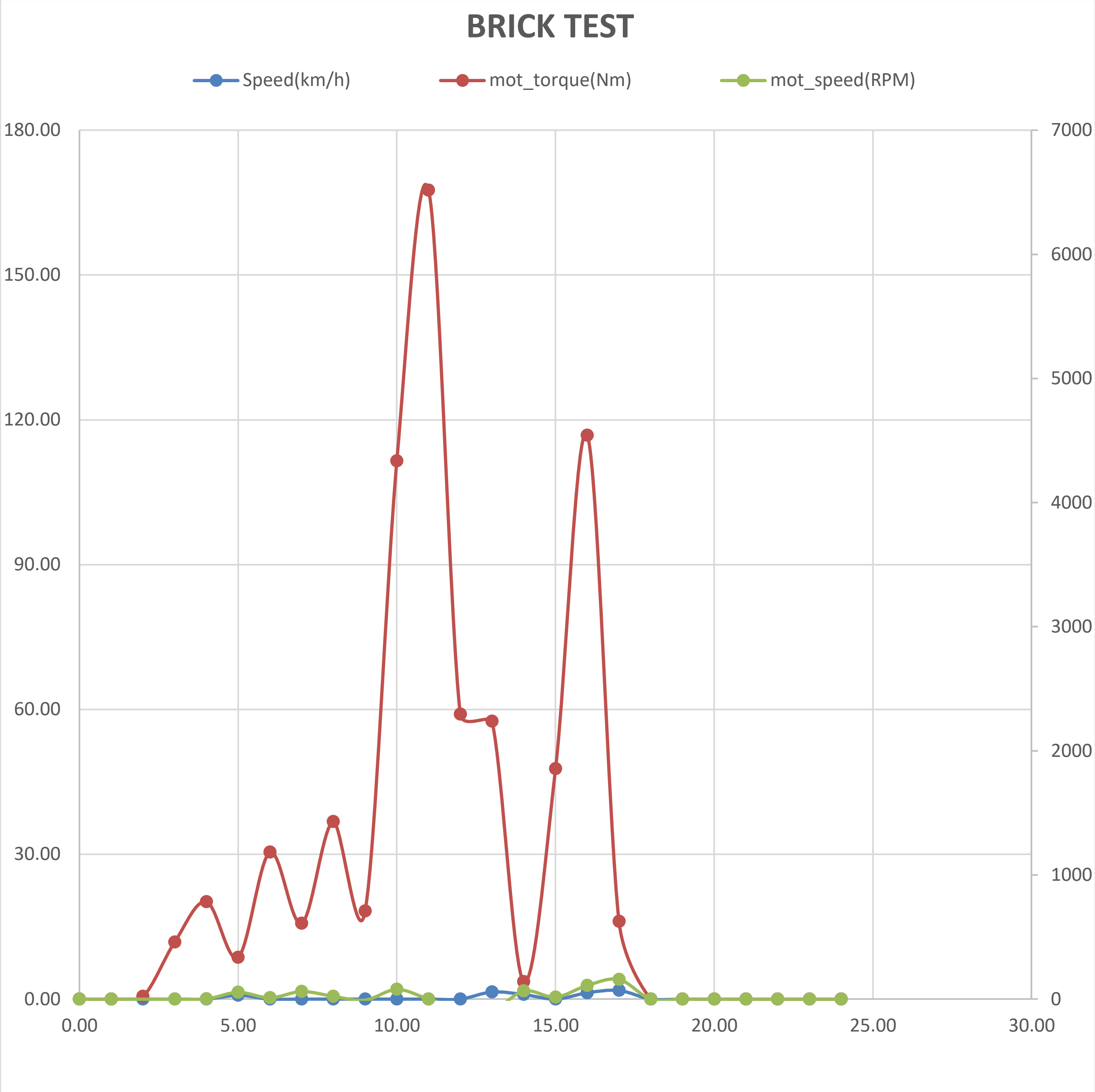

Fig. 15 Graph of some motor values during the brick test (on the left motor torque and vehicle speed; on the right axis motor rpm)

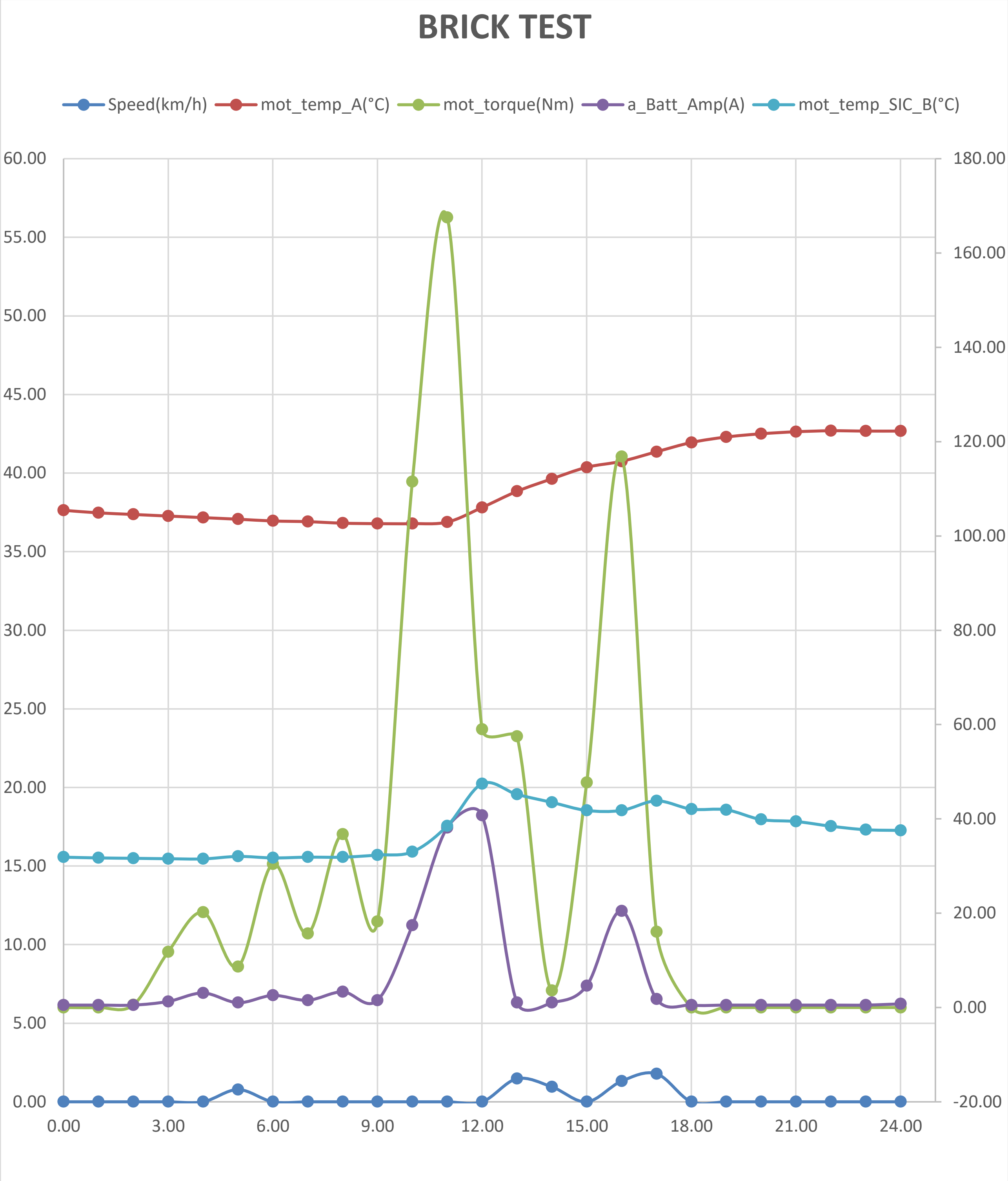

Fig. 16 Graph of motor values during the brick test (on the left axis the temperatures; on the right axis current and torque)

4.2.2 Acceleration Test

Test target:

This test evaluates the behaviour of the motor at high torque and low motor rpm

Boundary conditions:

The ambient temperature is about 25°C. The SoC of the battery pack is 80%.

Test Procedure:

1. the van is stationary at the beginning of the track
2. the accelerator pedal is pressed all down (100%)
3. the test finish when the vehicle reaches 60 km/h
4. recovery run at low speed to return to the starting point
5. repeat all 3 times

Exemptions:

The test times were decreased from 10 to 3.

The acceleration test has been performed by timing 0-60km/h instead of 0-100km/h.

Results and comments:

The test has been repeated 3 times, in all of them the vehicle was quite responsive to the throttle command and all the components of the powertrain withstand without problems. In Fig. 17, we can see that the max current requested during the test by the inverter exceeds 200 amps. In Fig. 18, we have the comparison between the electric power of the battery and the power of the motor during one of the tests. In Fig. 19, we can see the trend of the motor temperatures during one of the tests. The three tests are very similar to each other, as shown in table 2, the maximum acceleration reached is 1.46 m/s2.

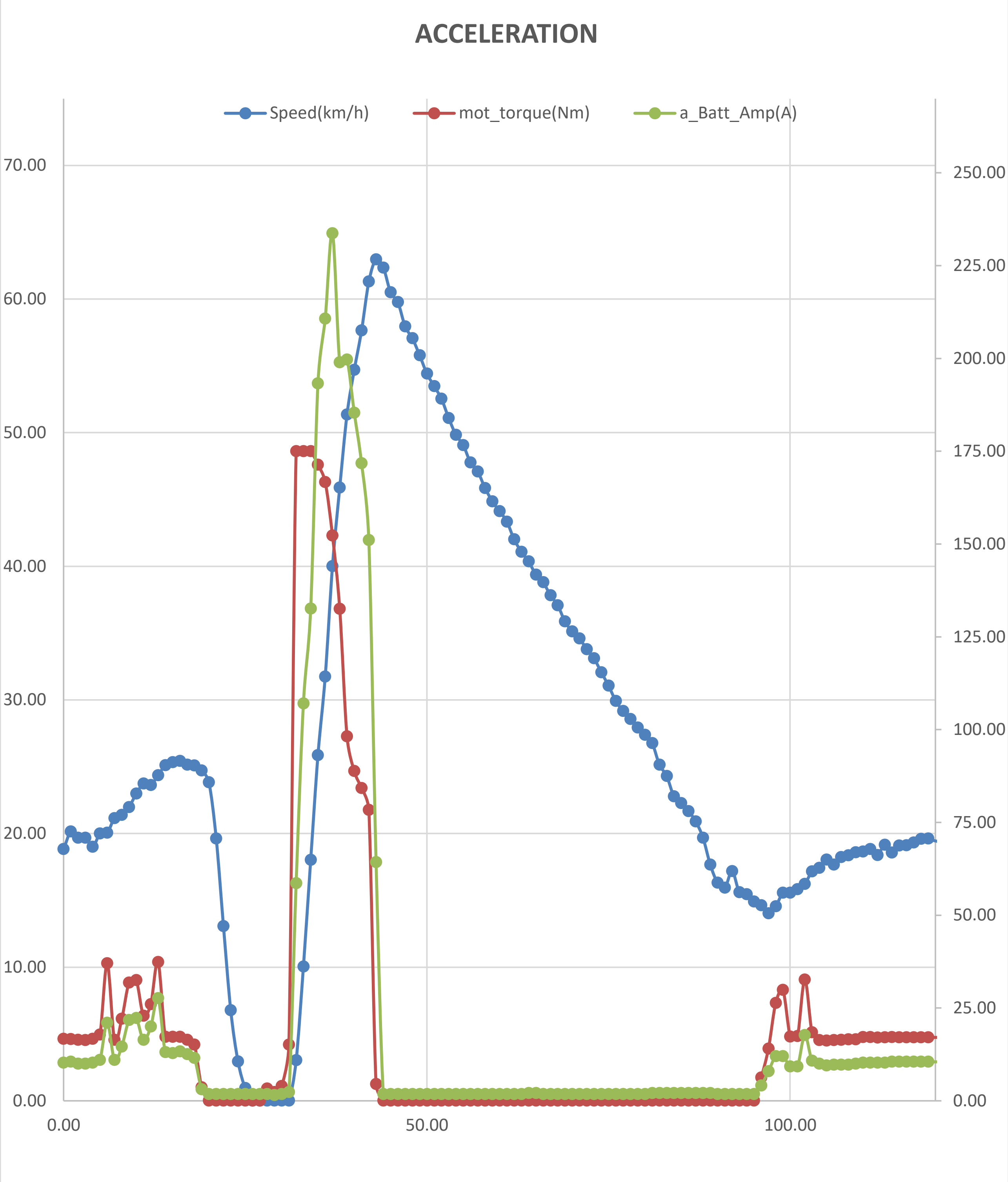

Fig. 17 Vehicle speed graph (on the left axis) and graph of torque and current (on the right axis) during the test

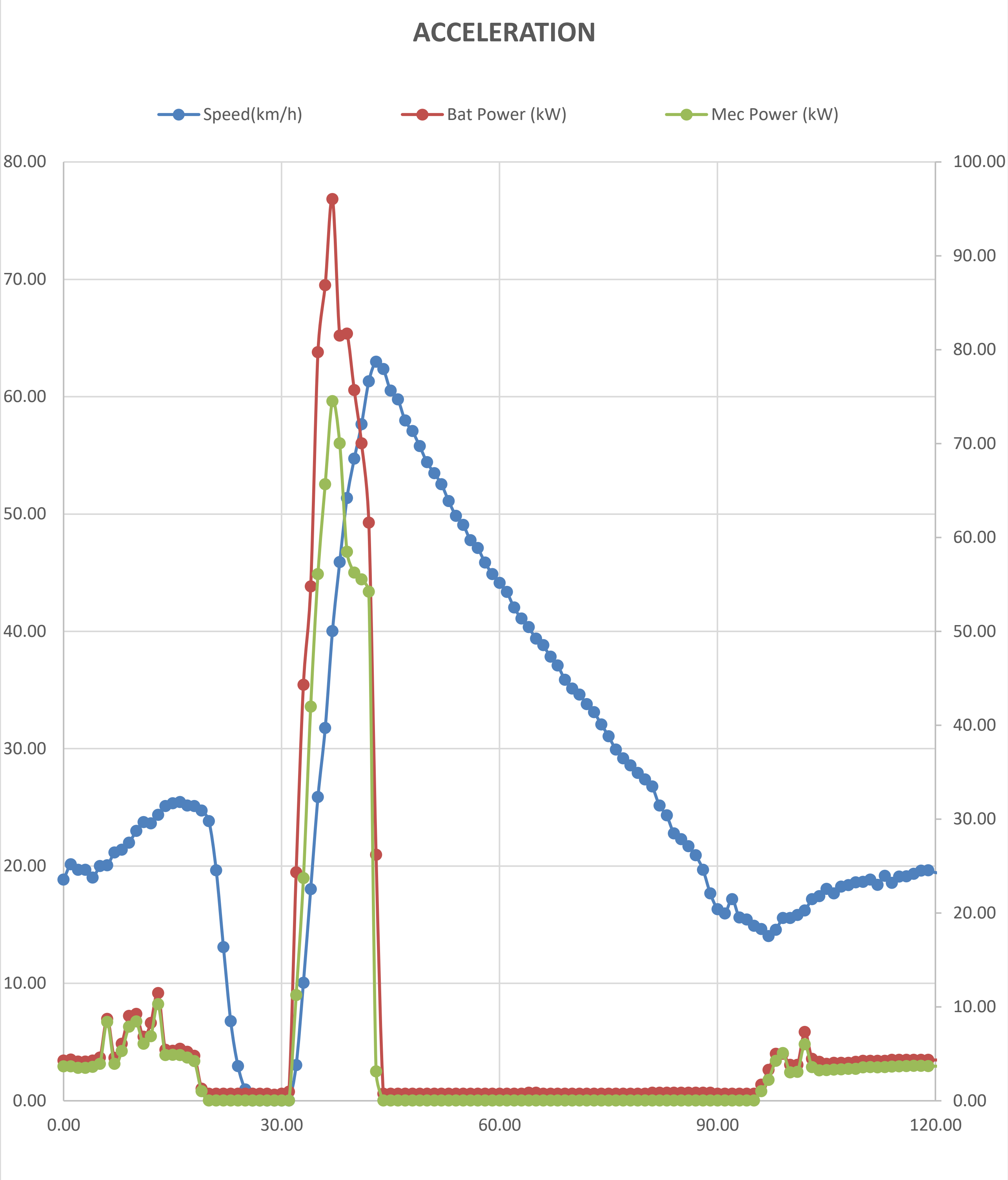

Fig. 18 Comparison between battery electric and motor mechanical power (on the left axis vehicle speed; on the right axis battery power and mechanical power)

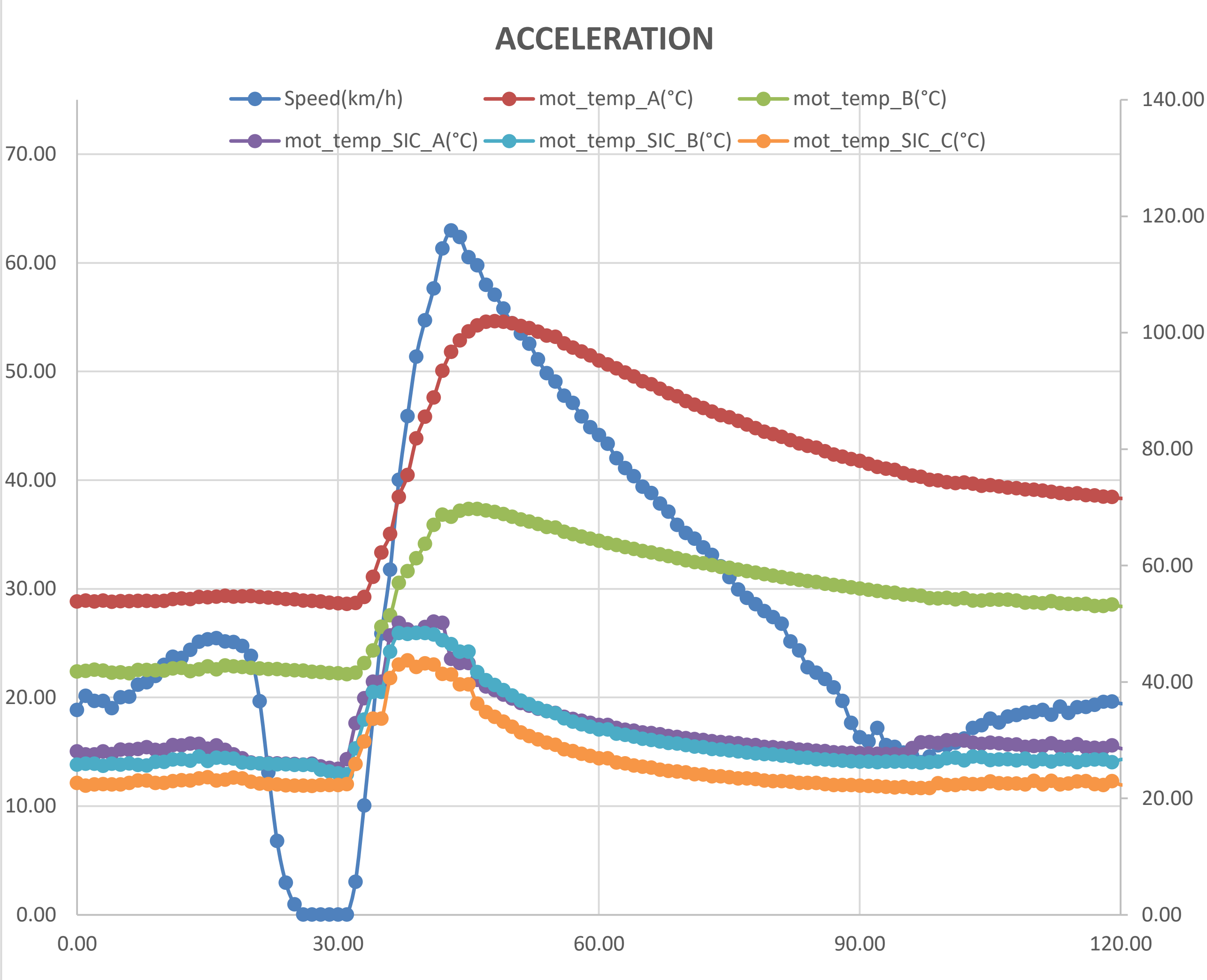

Fig. 19 Trend of engine temperatures during tests (on the left vehicle speed; on the right axis motor temperatures)

Table 2: A summary of the results achieved for the acceleration test

	Fisrt test	Second Test	Third Test
Max Speed (km/h)	62,97	63,14	63,23
Start Speed (km/h)	0,00	0,00	0,00
Max Motor Speed (RPM)	6662,00	6586,00	6740,00
Max Torque (Nm)	174,97	174,97	174,97
Time (s)	12,00	14,00	12,00
Acceleration (m/s2)	1,46	1,25	1,46
Energy (kWh)	0,2142	0,2204	0,2134
Start SoC (%)	80,00	79,00	77,00
End SoC (%)	80,00	78,00	77,00
Start max motor Temp (%)	53,37	61,44	71,22
Final max motor Temp (%)	96,67	104,27	114,32

4.2.3 Maximum speed Test

Test target:

This test evaluates the behaviour of the motor at high rpm and low torque, where the motor works mainly in flux weakening region.

Boundary conditions:

The ambient temperature is about 25°C. The SoC of the battery pack is 88%.

Test Procedure:

1. the van arrives at the starting point with a speed of 15 km/h
2. the accelerator pedal is pressed all down (100%)
3. the test finish when the vehicle reaches the track end
4. recovery run at low speed to return to the starting point
5. repeat all 3 times

Exemptions:

The test times were decreased from 10 to 3.

The van does not start from a standstill but with a speed of 15 km/h

Results and comments:

The maximum speed that the vehicle can reach on the test track is 82-83km/h, as shown in table 3, a longer track would have allowed 3 or 4 km/h more. This measure is in line with what tested on the bench considering the loss of the mechanical transmission. The van does not reach the target maximum speed was 120 km/h. In Fig. 21, Fig. 22 and Fig. 23, we observe the trend of the power, torque and temperatures of the motor and the battery pack current.

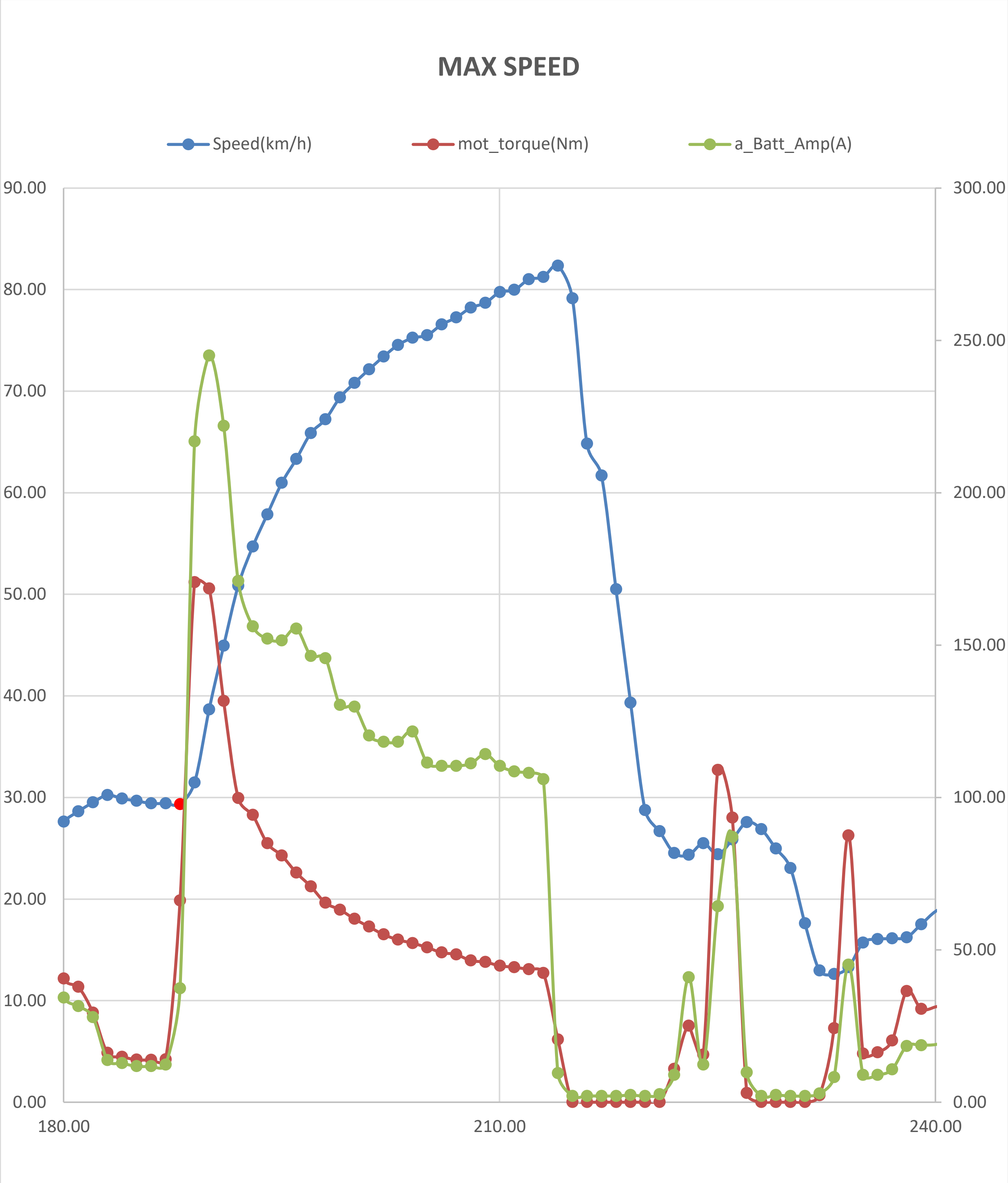

Fig. 21 Vehicle speed graph (on the left axis) and graph of torque and current (on the right axis) during the test

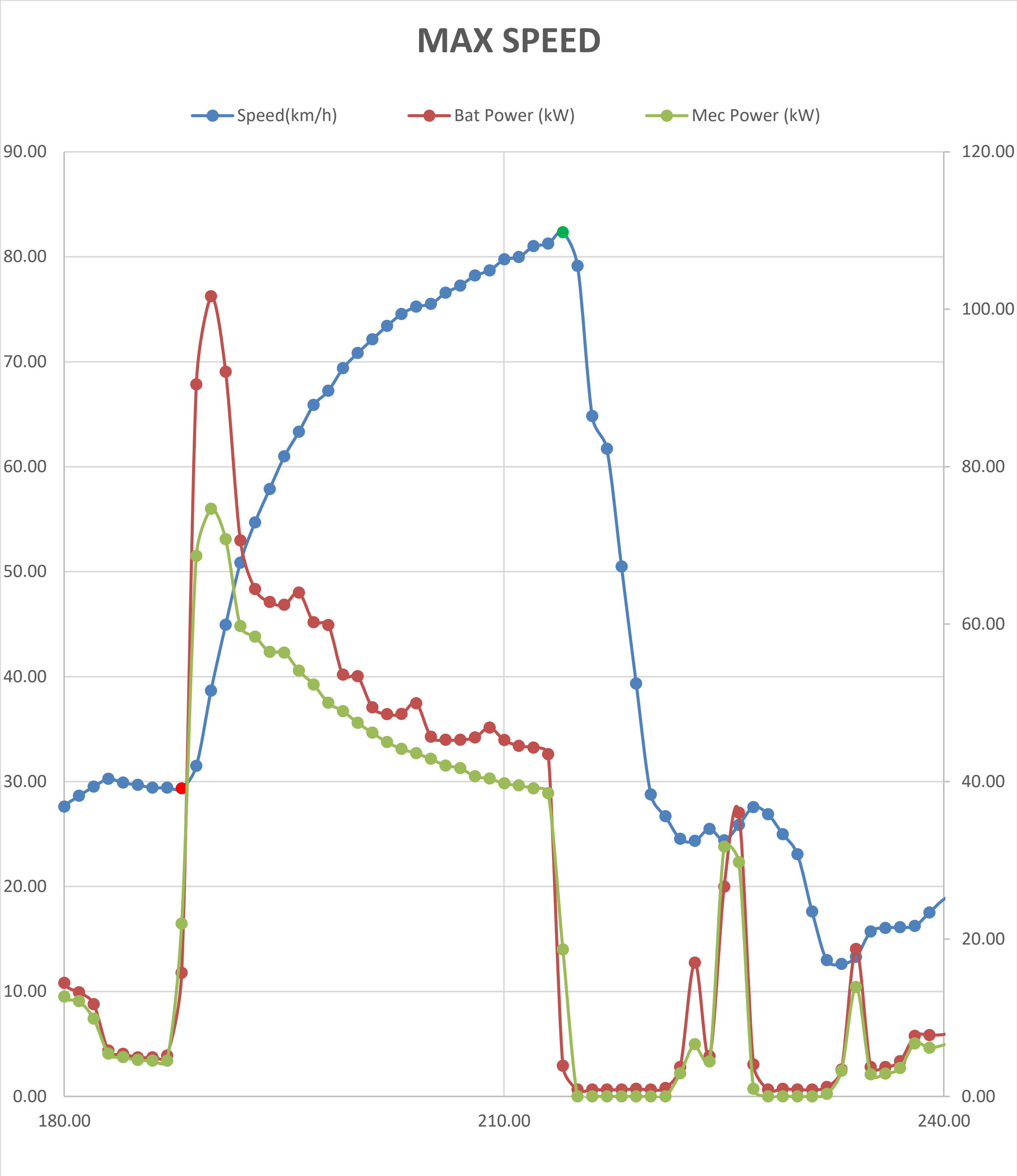

Fig. 22 Comparison between electric and mechanical power (on the left axis vehicle speed; on the right axis battery power and motor power)

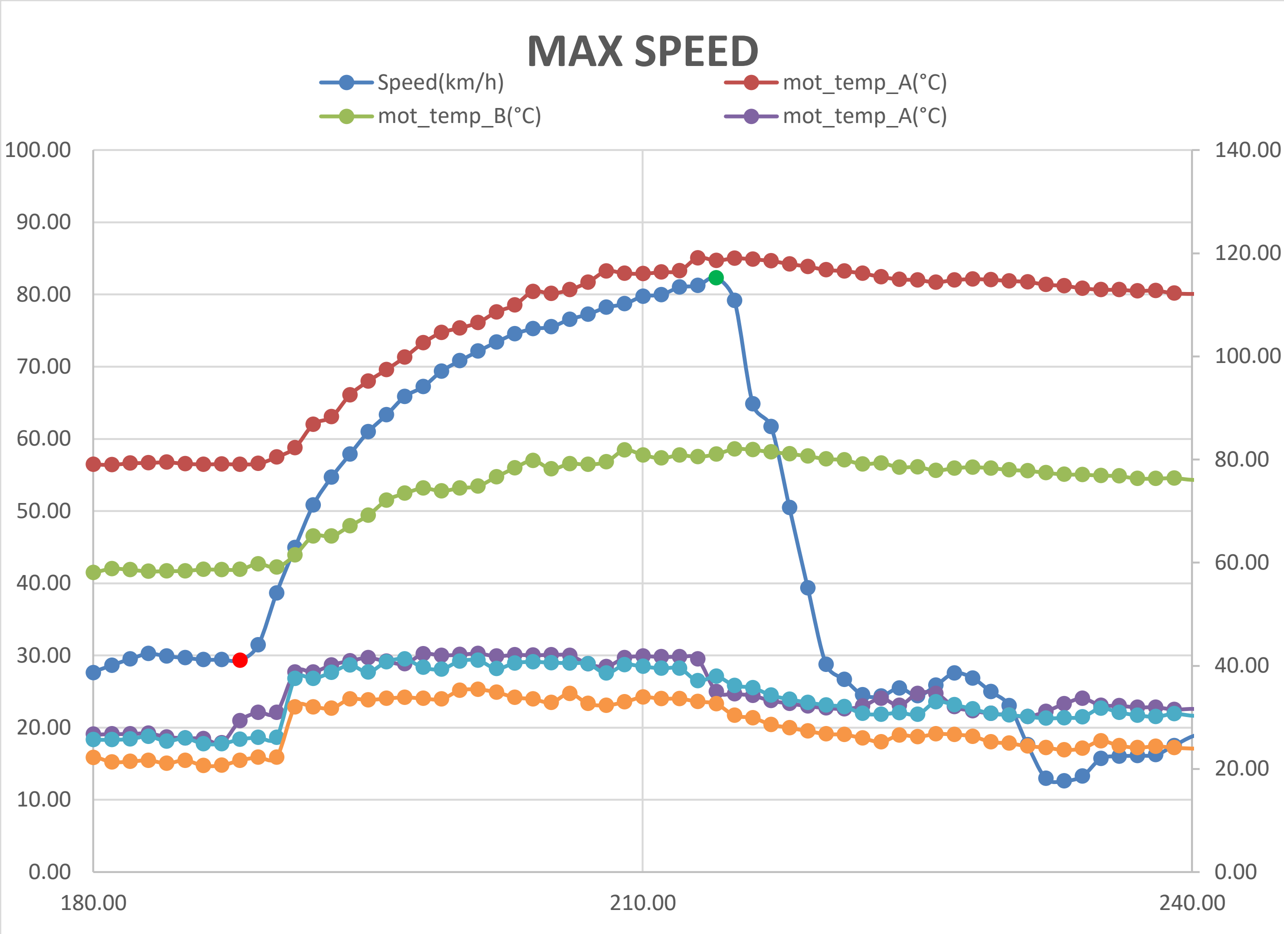

Fig. 23 Trend of engine temperatures during tests (on the left vehicle speed; on the right axis motor temperatures)

Table 3: A summary of the results achieved for the max speed test

	Fisrt test	Second Test	Third Test
Max Speed (km/h)	77,56	82,34	82,49
Start Speed (km/h)	29,51	29,36	32,25
Max Motor Speed (RPM)	8206,00	8668,00	8728,00
Max Torque (Nm)	171,59	170,62	166,12
Time (s)	22,00	26,01	26,00
Acceleration (m/s2)	0,61	0,57	0,54
Energy (kWh)	0,3534	0,4052	0,3997
Start SoC (%)	88,00	86,00	83,00
End SoC (%)	86,00	84,00	82,00
Start max motor Temp (%)	93,52	79,04	84,02
Final max motor Temp (%)	123,24	118,56	121,19
Global Eff (%)	92,40	89,55	90,05
Rest Time (s)	-	141,01	134,02

4.2.4 Constant speed Test

Test target:

This test evaluates the efficiency of the system at different speeds typical of an urban drive cycle

Boundary conditions:

The ambient temperature is about 25°C. The SoC of the battery pack is 73%.

Test Procedure:

1. the van is stopped at the starting point
2. the van is accelerated to the desired speed (20, 35 or 50 km/h)
3. the driver tries to maintain speed for at least 10s
4. repeat at different speeds

Exemptions:

None

Results and comments:

The constant speed test has been carried out to evaluate the efficiency of the system at different rpm typical of an urban use of the vehicle. In Fig. 25 is shown the trend of the vehicle speed, the power absorbed by the battery and the power delivered by the motor, during the test. The table 4 shows as test results a consumption of 0,19kWh/km at 20km/h, 0,21kWh/km at 35km/h and 0,24kwh/km at 50km/h.

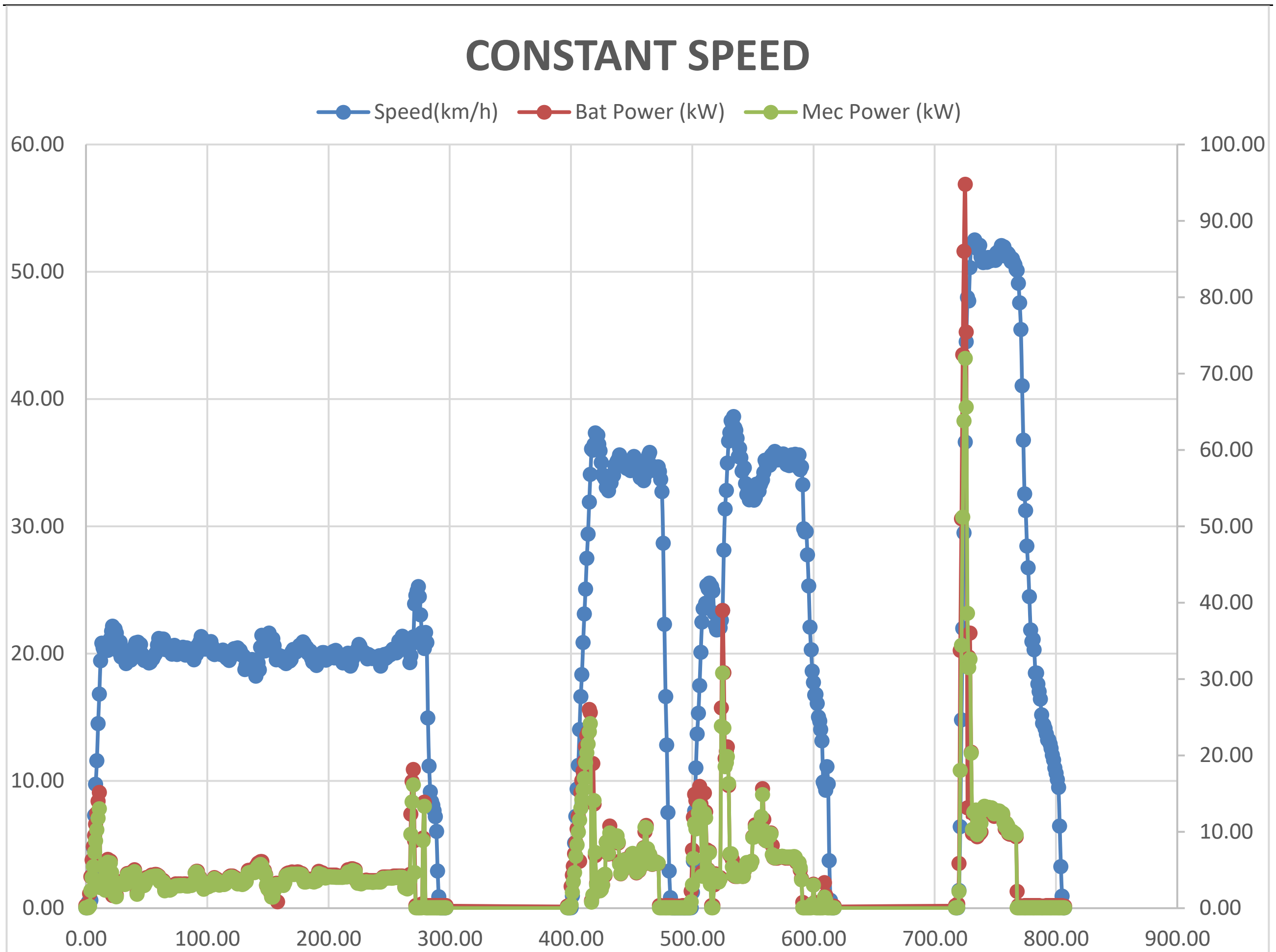

Fig. 25 The trend of the vehicle speed(on the left axis), the power absorbed by the battery and the power delivered by the motor(on the right axis), during the test

Table 4: A summary of the results achieved for the constant speed test

	20 km/h	35 km/h	50 km/h
MAX Speed (km/h)	22,15	36,91	52,49
min Speed (km/h)	18,20	32,03	50,09
Med Speed (km/h)	20,08	34,55	51,28
Med Motor Speed (RPM)	2129,49	3641,28	5418,63
Med Torque (Nm)	16,67	18,84	21,34
Time (s)	258,04	53,01	39,01
Med Current (A)	9,69	7,20	46,28
Energy (kWh)	0,2811	0,1081	0,1383
Start SoC (%)	73,00	71,00	68,00
End SoC (%)	72,00	70,00	67,00
Start max motor Temp (°C)	68,48	59,59	63,35
Final max motor Temp (°C)	54,69	56,67	65,40
Distance (km)	**1,44**	**0,51**	**0,56**
Consumption (kWh/km)	0,1953	0,2124	0,2489
Rest Time (s)	-	62,01	137,00

4.2.5 WLTP

Test target:

The WLTP test has the main purpose of checking the energy consumption in a real driving cycle test used as a reference of comparison with other vehicles. Due to the performance of the electrified Sprinter, it was possible to perform the WLTP low and medium.

Boundary conditions:

The ambient temperature is about 25°C. The SoC of the battery pack is 90%.

Test Procedure:

The WLTP is a standardized test therefore for further details we refer to the UNECE R.154 regulation

Exemptions:

The test, as agreed, was carried out on a circuit and not in the laboratory, introducing several errors in following the speed profiles of the test.

Results and comments:

The goal of the WLTP is to reproduce a driving cycle to compare the different emissions and consumption between vehicles. In our case, being an electric vehicle, CO2 emissions are zero, having tested only one motor we cannot compare its consumption. The main results are shown in table 5 and table 6. In Fig. 27 and Fig. 28, we can see how several vehicle parameters change during the driving cycle.

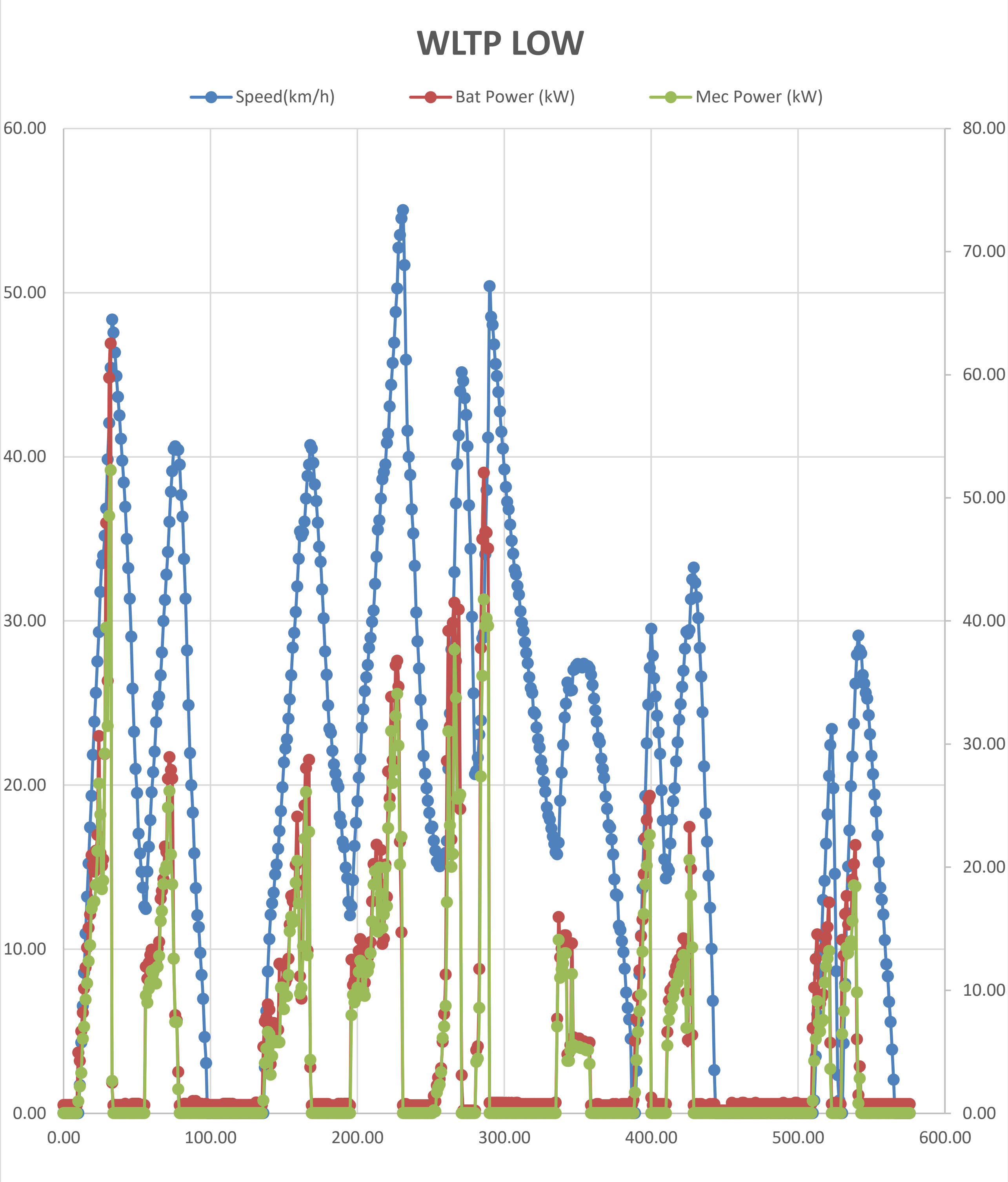

Fig. 27 WLTP cycle at low speed (on the lx axis vehicle speed, on the Rx axis battery and motor power)

Table 5: A summary of the results achieved for the WLTP LOW test

	WLTP LOW
Med Speed (km/h)	19,11
Energy (kWh)	1,06
Consumption (Wh/km)	345,17
Med Power (kW)	6,60
Min Power (kW)	0,21
Van service consumption (kWh)	0,03
Start Voltage (V)	428,02
Start SoC (%)	90,00
End Voltage (V)	415,29
End SoC (%)	80,00
High Current (A)	151,81
Peak Power (kW)	62,52
Med Motor power (kW)	5,26
Max Torque (Nm)	120,39
Max Speed (rpm)	5828,00
Max Motor power (kW)	52,24

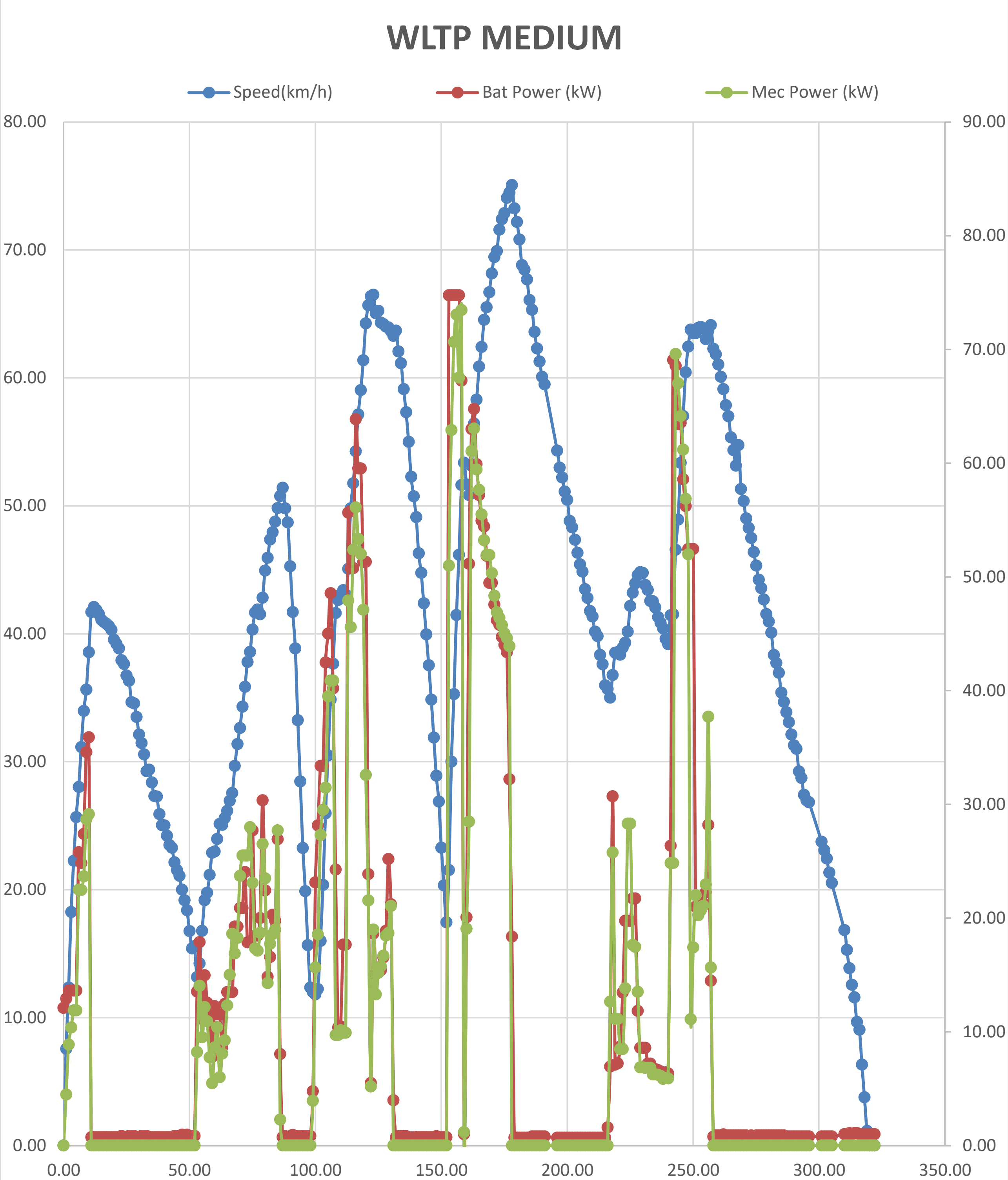

Fig. 28 WLTP cycle at Medium speed (on the Lx axis vehicle speed, on the Rx axis battery and motor power)

Table 6: A summary of the results achieved for the WLTP MEDIUM test

	WLTP MEDIUM
Med Speed (km/h)	41,00
Energy (kWh)	1,19
Consumption (Wh/km)	324,52
Med Power (kW)	13,70
Min Power (kW)	0,68
Van service consumption (kWh)	0,06
Start Voltage (V)	407,12
Start SoC (%)	75,00
End Voltage (V)	384,03
End SoC (%)	49,00
High Current (A)	192,00
Peak Power (kW)	74,76
Med Motor power (kW)	11,97
Max Torque (Nm)	173,14
Max Speed (rpm)	7940,00
Max Motor power (kW)	73,44

5 Conclusions

The realization of the vehicle demonstrator, based on an electric retrofit of a Mercedes Sprinter, was a complex work and needed mechanic, power electric and electronic specific skills.

All the activities are designed to face all the possible issues before the in-vehicle integration.

The result has been an easy work of fine tuning once the vehicle was assembled and prepared for the road, carried out with the other ReFreeDrive partners.

Unfortunately, as stated above it was not possible to compare all the different motors. However, the Pure Synrel motor and its power electronic were successfully tested and the overall performances were in line with the expectations.

Future improvements of the powertrain would be a higher reduction ratio, to better use the power of the motor and to reach a higher maximum speed. Another point to develop is a more efficient cooling system for the motor stator that would allow better usage of the torque.