D7.4: Paris urban area UC-2 complete solution description

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D7.4: Paris urban area UC-2 complete solution description

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Technical References

Project Acronym	INCIT-EV
Project Title	Large demonstration of user centric urban and long-range charging solutions to boost an engaging deployment of electric vehicles in Europe
Project Coordinator	CIRCE Miguel Zarzuela - mzarzuela@fcirce.es
Project Duration	01/2020 – 12/2023

Deliverable No.	D7.4 - Paris urban area UC-2 complete solution description
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[1] PU = Public

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Document history			
V	**Date**	**Partner(s)**	**Action**
V0.1	06/04/22	CIRCE	Table of Content available for WP7 and WP8 deliverables
V0.2	29/06/22	COLAS	First Draft. Contribution from all partners
V0.3	05/07/22	CIRCE	First Revision as WP leader
V0.4	20/08/22	COLAS	First Consolidated version
V0.5	06/09/22	VEDECOM	Second Consolidated version
V1.0	06/09/22	CIRCE	Final Quality Review from Coordinator

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0 EXECUTIVE SUMMARY

This document is the deliverable "D7.4 – Paris urban area UC-2 complete solution description" of the H2020 project INCIT-EV (project reference: 875683).

The main objective of this deliverable is to collects the main conclusions reached after finalizing the modelling, basic and detail engineering, and equipment development activities before the deployment of the UC-2

At this document the complete solution of the UC-2 for the wireless charging lane in Paris is descripted. The system, architecture and integration aspect are presented to explain how the final solution will work in the demo site.

The delivery of this deliverable is done in accordance to the description in the Grant Agreement Annex 1 Part A with an installation delay of about 5 months from the original planning.

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Table of content

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List of figures

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List of tables

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ACRONYM LIST

Table 1 Acronym List

Acronym	Definition
AC	Alternating Current
BOM	Bill Of Materials
DC	Direct Current
DWPT	Dynamic Wireless Power Transfer
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Field
EV	Electric vehicle
LQI	Line Quality Indicator
LCP	Liquid Cold Plates
PLC	Packet Loss Concealment
PWM	Pulse-width modulation
VMA	Vector Network Analyser

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1 INTRODUCTION

INCIT-EV aims to demonstrate an innovative set of charging infrastructures, technologies, and associated business models, ready to improve the EV users experience beyond early adopters, thus, fostering the EV market share in the EU. The project will seek the emergence of EV users' subjective expectations. 5 demo environments at urban, peri-urban, and extra-urban condition will be ready for the deployment of 7 use cases addressing:

- UC1: Smart and bi-directional charging optimized at different aggregation levels – Amsterdam – Utrech Area
- UC2: Dynamic wireless charging lane in urban areas - Paris
- UC3: Dynamic wireless charging for long distances -Versailles
- UC4: Charging Hub in a Park&Ride facility – Torino
- UC5: Superfast charging systems for EU corridors - Tallin
- UC6: Low power DC bidirectional charging infrastructure for EVs, including two-wheelers.
- UC7: Opportunity wireless charging

1.1 Contribution to INCIT-EV Objectives

WP7 and WP8 "Use Cases deployment and demonstration in urban and extra-urban areas" of the INCIT-EV project aims to model, design and develop the use cases to be demonstrated in all areas with aim of collecting real data from the field. The specific objectives are:

- To elaborate a plan for the successful deployment of the innovative use cases to be demonstrated (D7.1 and D8.1)
- To model, design and develop the different solutions addressing to be implemented in the project
- To commission all the developed equipment and prepare the field for the demonstration activities.
- To carry out the demonstration activities of the use cases, monitoring the defined KPIs for its ulterior contrast and analysis.
- To analyse the medium and long-term impacts of the use cases evaluating their techno-economic, environmental, regulatory and social aspects.

This deliverable collects the main conclusions reached after finalizing the modelling, basic and detail engineering, and equipment development activities before the deployment of the UC-2

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1.2 Contribution from partner table

Table 1 - Contribution table

Partner	Contribution
3. Vedecom	Design, engineering and performances tests on coils and inverters
4. UGE	Numerical simulation on coils and asphalt pavement
6. Colas	Project management and equipment purchase
8. Enedis	Grid connection and power quality measurements

1.3 Relation to other project activities table

Table 2 - Relation to other project activities table

Task	Relation to other project activities
T3.4 – Dynamic Wireless Power Transfer. Urban and extra-urban charging	Theorical modelling of the solution
T7.5 - Evaluation and impacts assessment	Short term impacts

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2 UC2 OBJECTIVES

Paris city UC2 will demonstrate a Dynamic Wireless Power Transfer (DWPT) technology to recharge electrical vehicles in motion for urban trips.

The demonstration aims to address different important aspects of a dynamic wireless charging system:

- **Interoperability between vehicles**: Three different vehicles, in two different power – passenger car (30kW) and light-duty vehicle (90kW) – will be charging at the same infrastructure.
- **Interoperability from systems and use cases**: The vehicles will be able to recharge in three different systems concepts and in very different conditions. The same vehicle will be charging at two urban areas: UC7 in Zaragoza for static wireless charging at 30 kW, UC2 in Paris for dedicated system at low speed (30km/h) and one extra-urban demonstration (UC3 in Versailles) reaching 85km/h at the same power (30kW and 90kW). The secondary and primary systems for the UC2 case are developed by VEDECOM .
- **Road integration**: The ground system will be completely integrated in the road construction process by the partners UGE and COLAS.
- **Live City demonstration:** The city of Paris will provide all technical support and proper authorization to install the charging system and run the demos.
- **Power grid integration**: The charging system will be connected to the AC grid provided by ENEDIS via an AC/DC with Power Factor Converter. Charging power available will be set at 120 kVA. COLAS partner will do the civil engineering work.
- **Communication system**: The charging station operation will be assured by a common communication system developed by VEDECOM and based on the ISO 15118 standard.
- **Lane keeping assist system**: A keep lane assistant will be used in the vehicles to assist the driver to reach the best alignment condition between the vehicle and the ground integrated coils.

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3 UC2 COMPLETE SOLUTION

The UC2 experimentation will quantify the efficiency of dynamic wireless power transfer in a street at Paris, where vehicles drive at low speed (up to 30 km/h) or are stopped when the traffic light is red.

The main guidelines of this installation are:

- One lane (one side of a road) is equipped
- The installation consists of 30 coils (each 102 cm long) embedded inside the base coat of the road, powered by 30 inverters located inside a technical channel, embedded under the pavement (sidewalk), themselves being powered and controlled by a power supply unit

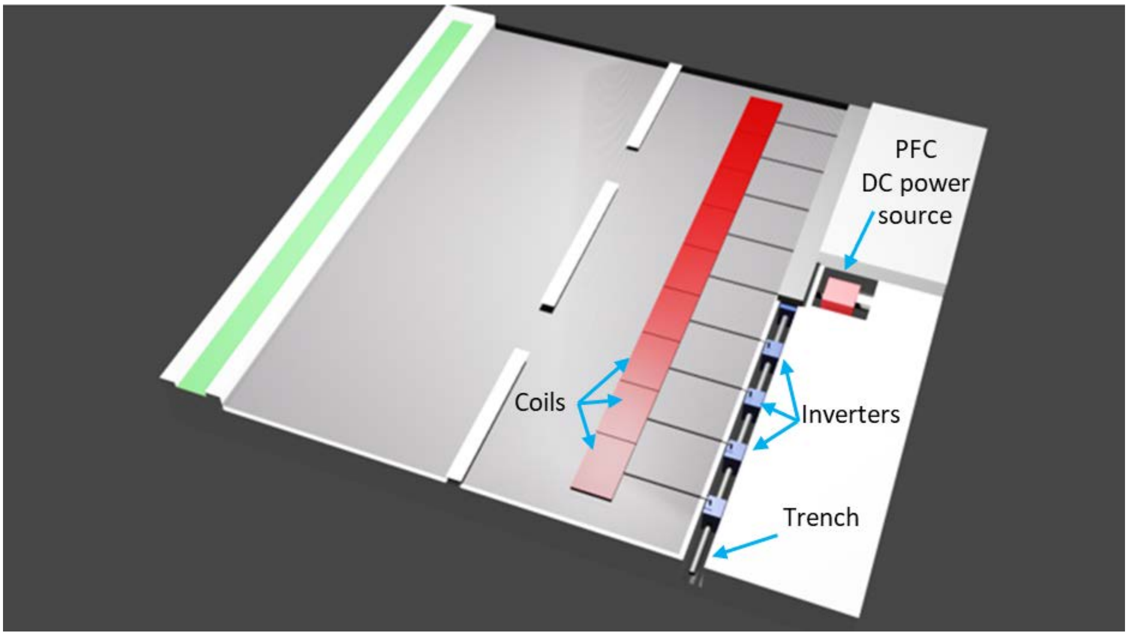

Figure 1 - Proposed installation

- The whole system is powered on only when experiments are conducted and under supervision of the demo partners.
- Only the coils located under the adapted vehicles are powered on. It occurs only after the adapted vehicles are identified by the road communication and control system.

The demonstration will take place at rue Thomas Mann (Paris), on one side of the road, along Jardin des Grands Moulins.

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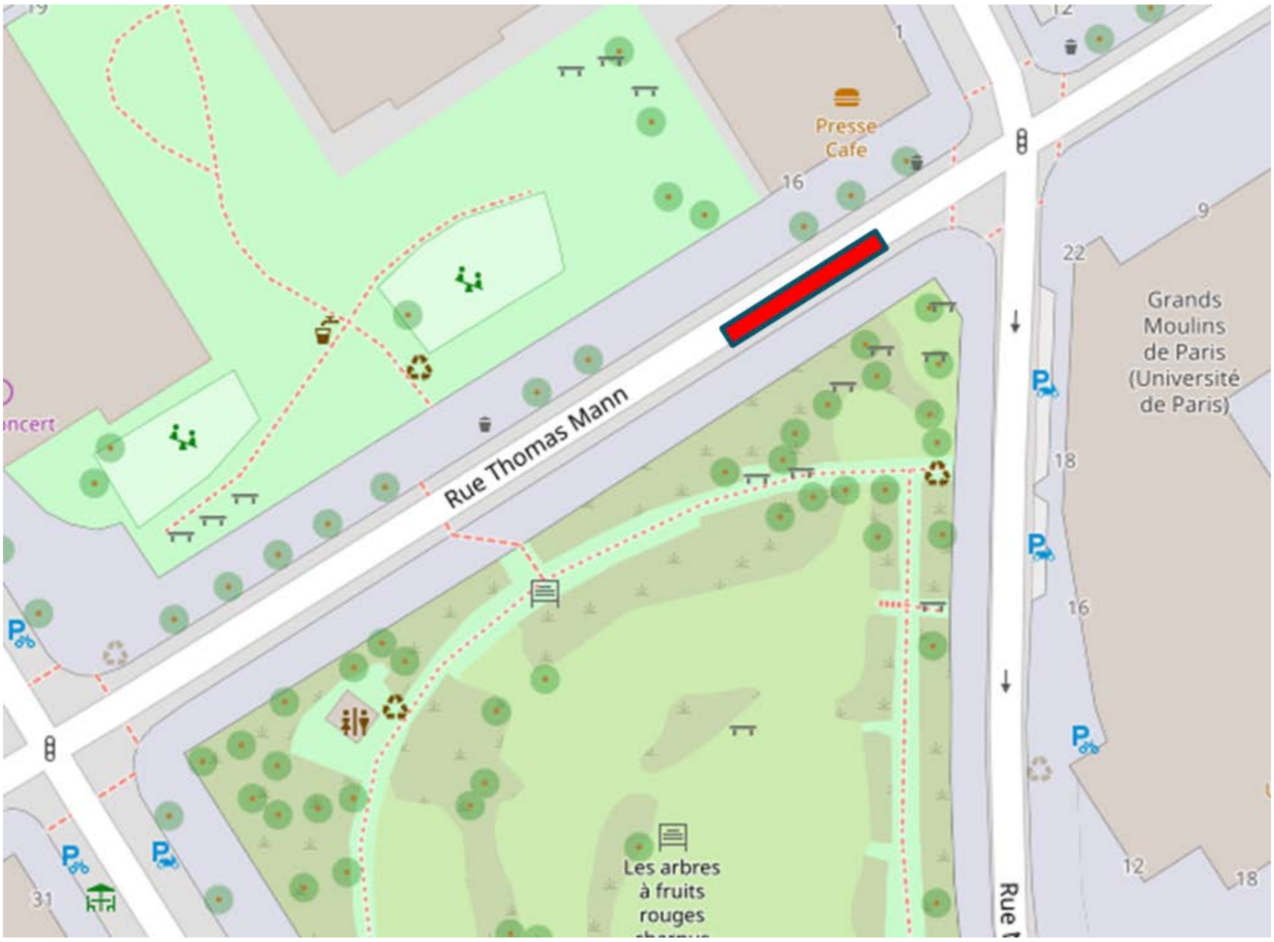

Figure 2 : Site location (map)

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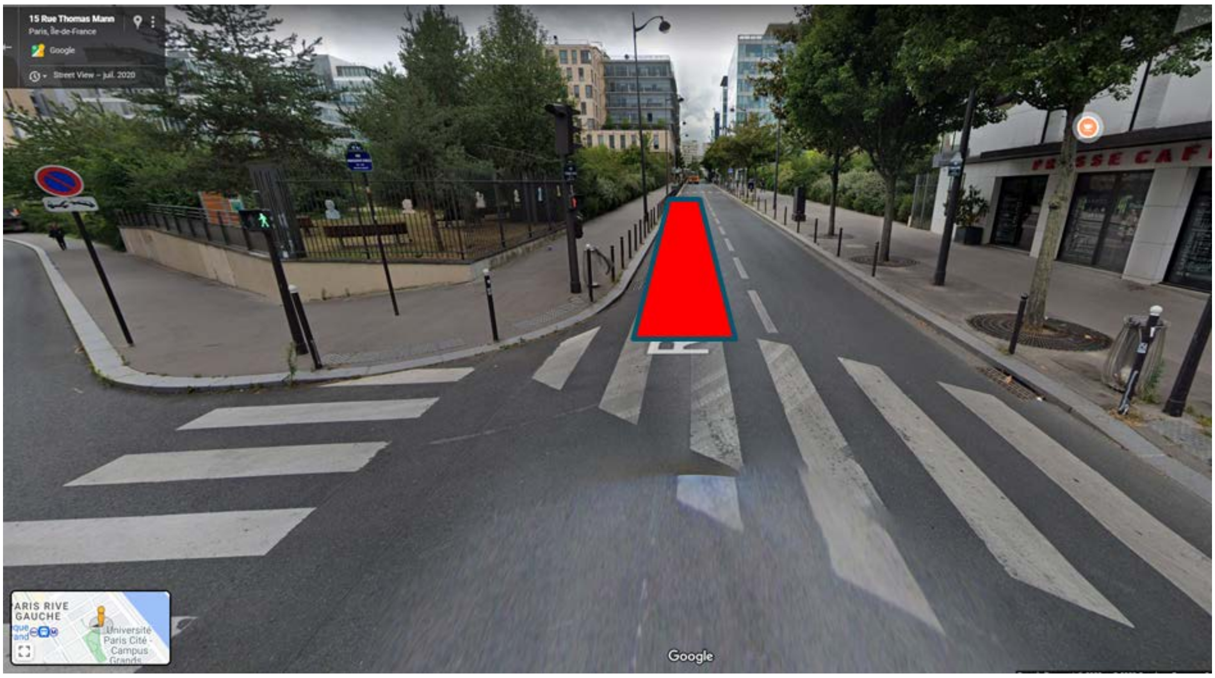

Figure 3 : Site location (picture)

3.1.1 Vehicles

Three different vehicles will be adapted to be charged on the wireless charging lane: a Renault Zoe, a Stellantis DS3 and a Renault Master. The following subsystems will be integrated in the vehicles:

1. Coil: A coil of 30kW nominal power will be attached to Zoe and DS3 vehicles, while three coils of 90kW total power will be installed in the Master vehicle. The three vehicles are shown in Figure 4.
2. Power converters: The AC/DC stage converters are responsible for the delivery of the power received by the coil to the vehicle battery.
3. Cooling system: a dedicated cooling system for the converters was developed, avoiding the use of the standard cooling system of the vehicle.
4. Lane keeping assistant: This system is composed of two cameras and a lane keeping assistant interface to help the driver to find the best positioning for the charging lane.
5. Communication system: A ISO15118 based protocol will be implemented and used to identify the vehicles to be charged.

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Figure 4 : UC2 Vehicles

3.1.2 Solution for pavement integration

3.1.2.1 Issues associated with pavement integration

IN WP4 of INCIT-EV, a state of the art and review of existing solutions has been carried out, and the following main technical questions, associated with road integration the charging system, have been identified:

- The choice of an appropriate pavement structure, and method of installation of the charging coils in the pavement structure
- The thickness of road materials on the primary coils, to ensure good charging efficiency
- The influence of the electromagnetic properties of the pavement materials (in dry and wet condition) on the performance of the charging system
- The operating temperature of the embedded coils, and its compatibility with the road materials
- The resistance of the coils and other elements placed in the road to the construction process (hot temperatures, compaction)
- The moisture protection of the different elements integrated in the road

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- The resistance to traffic loads of the different elements integrated in the road structure, and more generally, of the complete E-road structure. The bonding of the integrated charging system with the surrounding pavement materials is, in particular, an important point
- The EMF emissions and EMC issues associated with the charging solution

Based on these technical questions, a methodology for defining the pavement integration solution has been proposed. The main steps of this methodology are the following:

- **Definition of the pavement structure and integration solution**.
- **Selection of appropriate materials**. This concerns the choice of a protective and insulating material for the coils, and also of pavement materials compatible with the charging system.
- **Laboratory testing** of the performance of the primary coils, embedded in pavement materials. Several aspects were studied:
  - The electromagnetic performance of the coils embedded in pavement materials (dry and wet).
  - The operating temperatures of the coils integrated in pavement materials.
  - The resistance of the coils to the construction process, and the mechanical behaviour of the embedded coils.
- **Mechanical and thermal modelling.** The objective is to define mechanical and thermal finite element models, which can be used to predict the response of the charging system embedded in the pavement. Such a model can be used for design purposes, or to evaluate the influence of different parameters on the response of the system (material properties, pavement structure, temperature, traffic loads).

3.1.3 Grid

Power supply

In order to connect to the grid the inductive system power, a dedicated power line is built under the pavement between the closest low power distribution station and a dedicated disconnection and protection cabinet.

The maximum power available on this line is designed to cover the requirement of the experimentation and will be able to provide up to 120 kVA through a 3 phases (400 V) power supply.

The dedicated aluminium cables will have a section of 150 mm2 each and will be laid down at 90 cm below the ground level, on a 30m length, under the curbside as it is standard practice in Paris.

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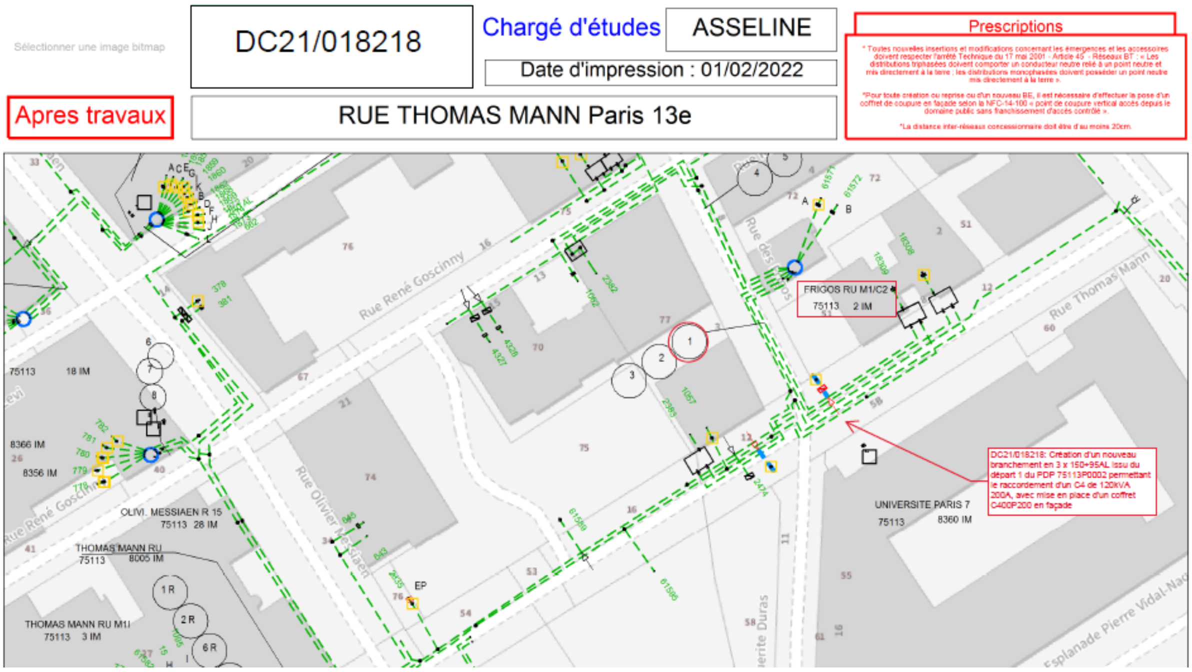

Figure 5 - Extract from the implementation study showing the electric power lines (green doted lines) between the low power distribution station (blue circle) and the electric cabinet location (red arrow).

The power supply deliver point to the experimental setup will be made available through a disconnection and protection cabinet which will provide a 400 A disconnection and a 200 A standard protection, a dedicated smart meter, a main switch and a connector panel.

3.1.4 Power supply

The main power supply is a 400 V 120 kW AC/DC power supply with an input of 380 V three-phase current. This rectifier (AC/DC) feed the 30 inverters (DC/AC) over a dispatch electrical cabinet.

3.1.5 Dispatch electrical cabinet

The cabinet will be fixed on the pavement with a concrete sealing and it is designed to be naturally ventilated and meets IP44 IK 10 protection standards.

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Figure 6 : Example of an electric cabinet

3.1.6 Technical channel for inverters

A technical channel made of pre-cast concrete will host the inverters and cables. Figure 7 illustrates the technical ground trench for the inverters.

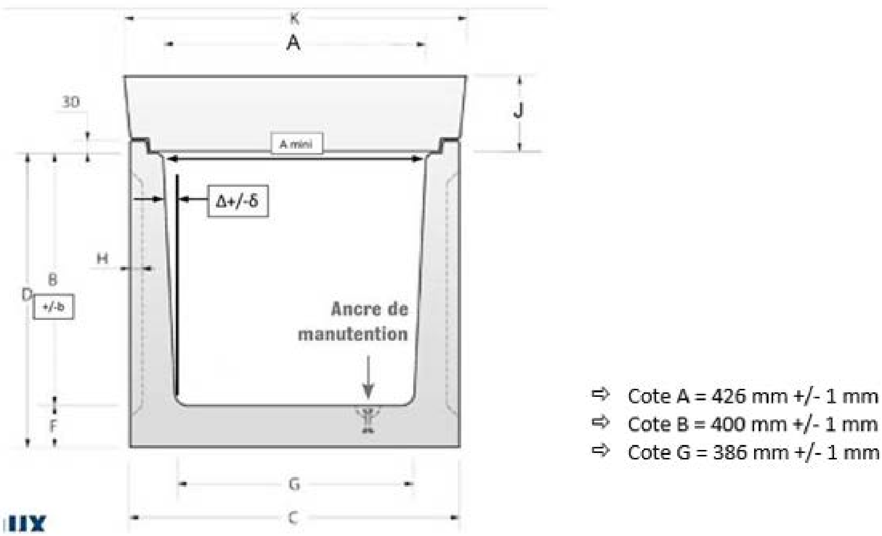

Figure 7 : Cross-section of the technical ground trench for the inverters

This technical channel is susceptible to the effects of bad weather; consequently, the inverters must be resistant to humidity

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3.1.7 Inverters

The obtained DC power from the power supply is converted into a high-frequency AC power to feed the transmitting coil through a compensation network (called series-series). The compensation network reduces the reactive power operating at the resonance frequencies. Indeed, the high positive reactive powers due to the leakage inductances at the two sides of the coils are compensated by capacitors to improve the power transfer capability and efficiency. The inverters are represented in Figure 8

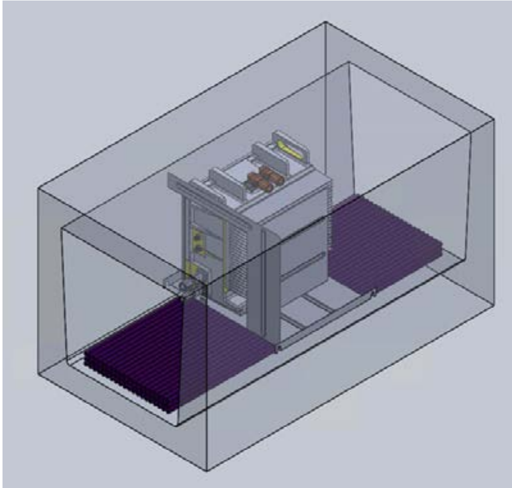

Figure 8: Power inverter inside the ground trench

3.1.8 Coils

As seen previously, a dynamic inductive charging system (DWPT) is composed of several coils embedded on the ground. In the UC2, the primary coils were developed by VEDECOM. Several versions have been considered within the framework of the project to integrate all the improvements of the design. The finally considered version consists of a rectangular coil with Litz cable loops, ferrite elements and a casing made of composite material. A schematic view of the final coil design is shown on Figure 9. Each coil is 120 mm long , 740 mm wide and 65 mm high.

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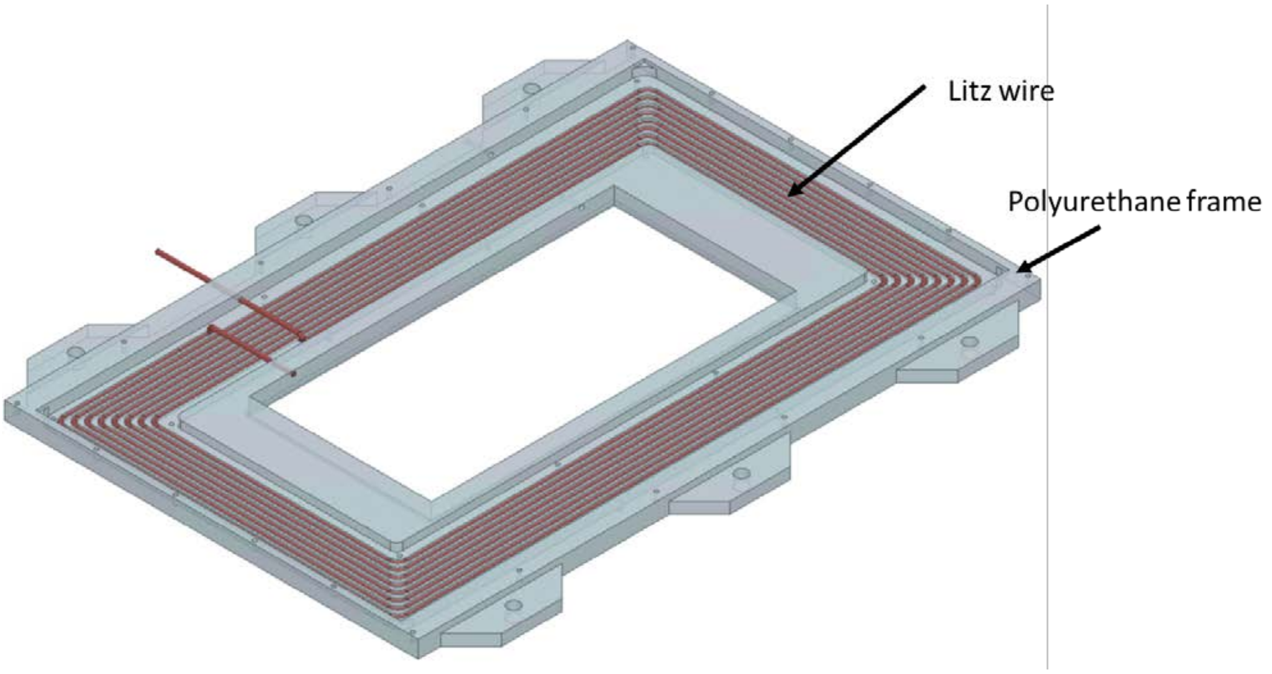

Figure 9 : Proposed design of Ground coils

The high-frequency current generated by the road inverters feed the ground coils, which generate an alternating magnetic field, inducing an AC voltage at the receiving coil port. Figure 10 shows the proposed design of the secondary coil (vehicle coil).

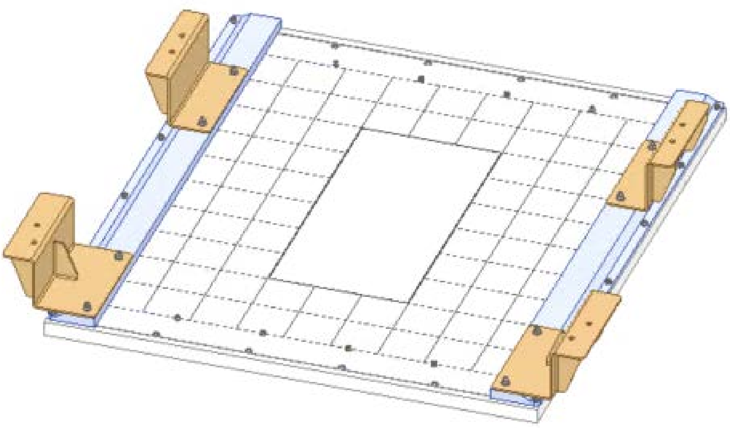

Figure 10 : Proposed design for Vehicle Coils

The induced AC voltage on this vehicle coil, is rectified using a DC to AC converter and transferred to a DC/DC charger to charge the EV battery.

3.1.9 Vehicle power adaptation

The vehicles will be subjected to several modifications in order to include the elements described in the previous sections. One of them is related to the power conversion necessary to recharge the battery. The

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current power electronics converters are presented on the Figure 11. An AC/DC converter and an DC/DC converter will be used to control the energy transfer in a safe way and to convert the power to the battery voltage level.

The vehicle integration details are still in development, but it's based on the schematic of the Figure 12.

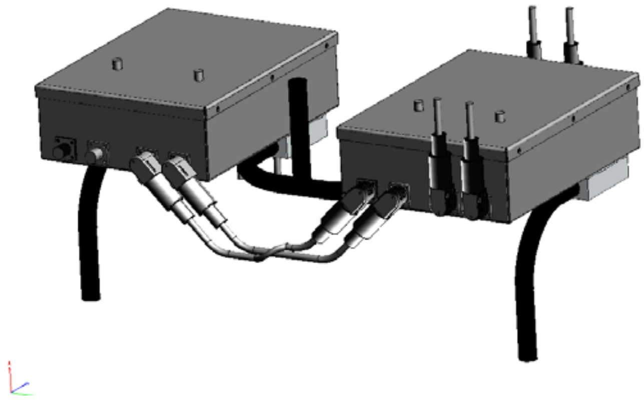

Figure 11: Power electronics inside de vehicle

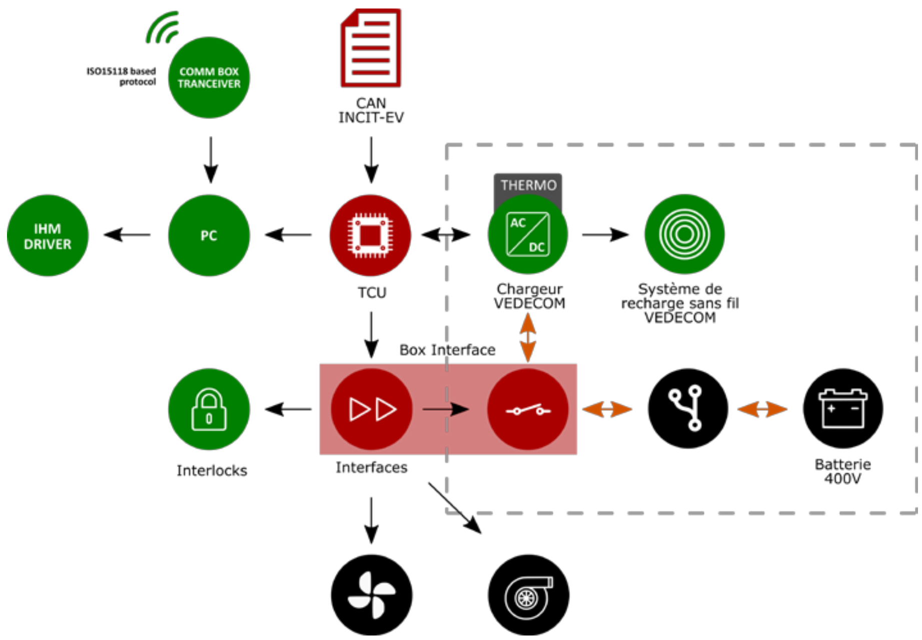

Figure 12: Basic schematic of vehicle system integration

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3.2 UC2 Final modelling and engineering results

3.2.1 Integration of coils inside asphalt pavements

3.2.1.1 pavement structure and integration solution

On the demonstrator, the coils will be integrated in a bituminous pavement structure. The proposed solution for road integration is the following: First, the existing pavement wearing course will be removed (milled). Then a trench, just slightly larger than the coils, will be milled in the base layer. The coils will be placed inside and sealed with an appropriate resin. Then, the trench will be covered with a new surface layer, covering the whole width of the road lane. The principle of this solution is shown on Figure 13.

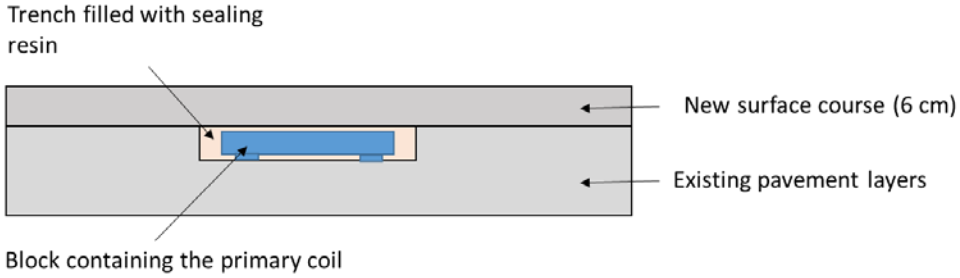

Figure 13 : Solution for pavement integration of the Vedecom charging coils

3.2.1.2 Material selection and laboratory testing

Testing of charging efficiency:

The first test performed consisted of evaluating the charging performance of the inductive coils once were embedded in pavement materials. For that purpose, tests were carried out on a test bench, specifically developed by VEDECOM for the testing of WPT systems. This test bench consists of a platform, where the primary coils are installed, and a robotized arm, which is used to move the secondary coil, to simulate the moving vehicle (seeFigure 14). The platform has a length of 5 meters, which allows to test several coils simultaneously.

Tests were performed on this test bench with the aim of evaluating the effect of pavement materials on the electromagnetic performance of the coils. Because the embedment of the coils in asphalt materials is an irreversible process, in the sense that the embedded coil cannot be removed and re-used, it was decided only to interpose plates of bituminous material between the primary and secondary coils

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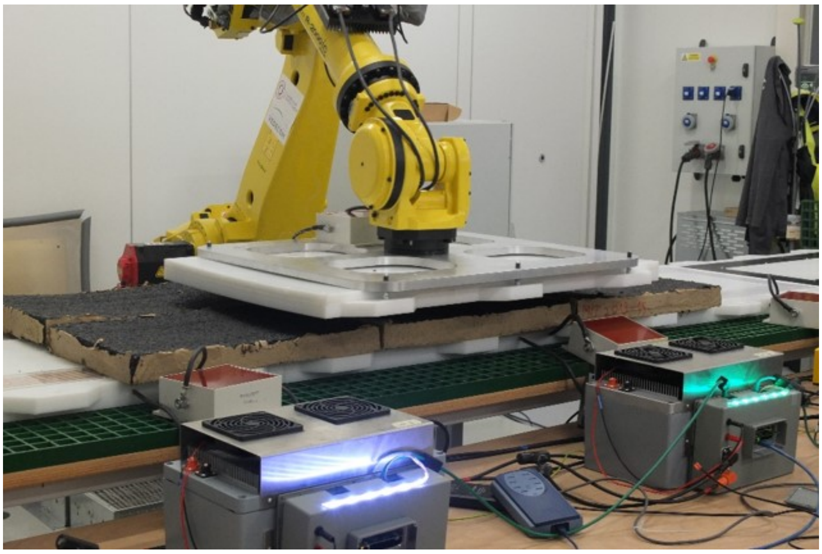

Figure 14 : View of the VEDECOM test bench for testing different road material for of inductive charging systems

The charging tests were performed with different distances between the primary and secondary coils (between 10 and 25 cm), and different conditions of alignment between the coils (up to +/- 25 % misalignment). The tests indicated only a very slight loss of transmitted power with the bituminous materials (maximum about 5 %). They also indicated a limited effect of the misalignment (maximum loss of efficiency of 3 % for +/- 25 % misalignment). In conclusion, these tests indicated a satisfactory performance of the charging system with interposed bituminous materials.

Testing of thermal behaviour:

A second series of tests were performed to measure the operating temperature of the coils once they were embedded in pavement materials. This measurement is important to evaluate the risk of reaching high temperatures when the coils are embedded in pavement materials, which could produce rutting of the bituminous materials. The maximum acceptable temperature for conventional asphalt materials is about 60 °C.

These temperature measurements were performed with the primary coils embedded in a granular material, identical to the granular skeleton of the asphalt material. The advantage of using a granular material is that it is possible to embed and remove the coil easily, without damaging it, which is not possible with an asphalt material.

These tests were performed in a plastic container, which was filled with granular material, and in which the primary coil was embedded. In these tests, 6 temperature probes were positioned at different depths, and at two different lateral positions (in the center of the coil, and near the Litz wires). The principle of the test set-up is shown on Figure 15.

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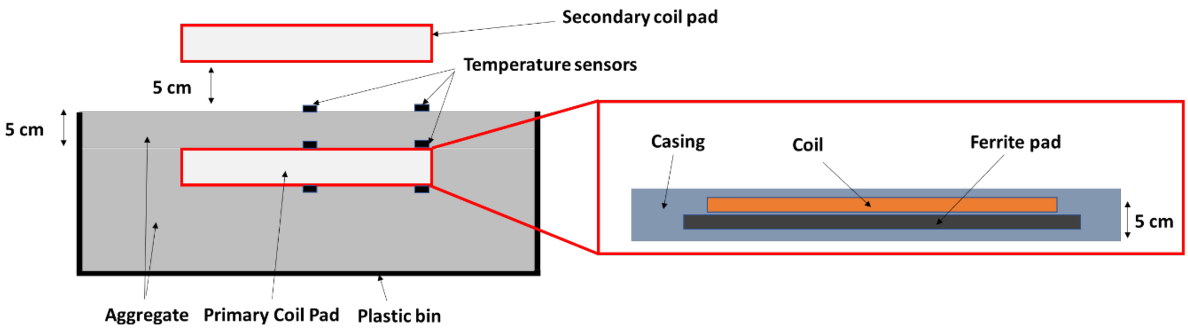

Figure 15 : Test setup for temperature measurements.

Temperature measurements were performed using this setup, with:

- different charging sequences, simulating the operating conditions of the urban demonstrator;
- dry and wet granular material (with a water content of about 3 %).

These temperature measurements, with the coils embedded in a granular material indicated that:

- The temperature variation is local, and mainly affects the Litz wire turns surrounding area for the test conditions applied, the maximum temperature increase (just above the coils) was about 8 °C after 2 hours, and 15 °C after five hours. These values were obtained with a 15 kW charging power, and 3 minutes on / 3 minutes off charging cycles.
- No significant influence of moisture (about 3 % of water) on the temperature variation and on the resistance of the embedded coil was observed.

Testing of mechanical behavior:

These tests were performed on several options for the coil container block, as well as for the coil sealing resin . To evaluate these materials, two main types of tests were made:

- four-point bending tests used to evaluate the strength of the interface between two materials (resin and coil block, or resin and asphalt material).
- wheel tracking tests, which consist on submitting the asphalt to moving wheel load. These tests were performed on slabs of asphalt material, in which a block, simulating the coil, was integrated.

These two types of tests were performed on 4 different candidate materials for the coil block, and 3 different sealing resins, allowing the selection of the block material and the resin. For the coil block, the material selected is a rigid polyurethane (PUR) specified with a high elastic modulus (4400 MPa at 20 °C), a high tensile strength, a good resistance to the hot asphalt mix temperature (160 °C) and a good bonding with the selected resin.

For the resin, a product called Plastiroc, used for sealing of pavement cracks, was selected. The tests indicated that this resin shows a good resistance to temperature 160 °C), a good bonding with the asphalt materials and with the coil block material (PUR), and a sufficient deformability to be able to follow the deformations of the asphalt material and coil block without cracking.

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3.2.2 Thermal simulations of inverters

3.2.2.1 Thermal management

During the energy conversion, losses (Joules) are generated. Even if efficiency is improved by new power electronics designs, these losses must be extracted by a cooling solution.

The UC2 has many sources of heat, inside or aside the road and inside the cars. These sources are mainly the converters and the coils.

At the experimentation location, the installation will count on one main AC to DC converter supplying energy to 30 DC to AC converters connected to 30 coils. Only the main converter will not be buried in the road.

The cars will carry at least one coil associated with a rectifier and a battery charger.

This chapter is divided in two main parts:

- Road equipment cooling.
- Cars equipment cooling

To cool all the elements and keep their temperature below the maximum values defined by the suppliers, the only medium available is the surrounding air.

In order to consider the worst environment conditions, the air maximum value will be considered to be 40 ºC for calculations.

3.2.2.2 Road equipment cooling.

The coils and the surrounding materials are managed from a thermal point of view by Gustave Eiffel University (in WP4 D4.10).

VEDECOM is focused on cooling solutions of the 30 converters. The actions are considering 2 main subjects:

- supporting the power electronic subcontractor for the selection of the heatsink attached to each converter
- developing the ventilation system to provide fresh air into the gutter where the converters will be buried

These two subjects are completely linked

3.2.2.2.1 Selection of the heat sink.

As the converter will be enclosed into a closed gutter buried in the ground, it is necessary to provide a forced air flow.

Initially, natural convection and conduction mechanisms were considered. It is possible to make calculations considering natural convection into the gutter; however, many parameters are not fully defined to calculate correctly heat conduction through the ground up to the air. In addition, using natural convection and conduction requires to consider the impact of the sun if tests are made during sunny days. Passive solar gain might be higher than heat losses from converters especially during the summer season.

A heat sink was pre-selected taking into account the following considerations:

- Heat losses expected by the converter supplier

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    - 180 W total dispatched equally to 2 power modules
- Maximum temperature required by the supplier to guarantee good working conditions
    - 90 °C at the surface of the power module
- Air flow expected to cool the converter

Before defining the air flow rate, it was required to decide how to distribute the air flow to each converter, in parallel or in series.

Considering the environment and the fact that converters must be protected from rain and dust, a parallel air distribution is not applicable. It is preferable that the air input and output were placed above the ground level. The option of having 30 intake grids and 30 outtake grids aligned with the surface has the disadvantage of not protecting the equipment from dirt and water. On the other hand, it is feasible to set up a full serial air distribution for the 30 converters, but the air allowed maximum temperature must be consider in that case. VEDECOM decided to limit the air output temperature to 60 °C with the objective to limit disagreement to pedestrians. The previously made consideration of 40ºC ambient temperature implies a maximum elevation of 20ºC. The current electrical setup will not allow to run the 30 converters simultaneously: only 120 kW are available. However VEDECOM decided to calculate a cooling solution able to allow a full test if needed. Additional costs are limited., and, during the current period, the losses estimations may change and increase (like solar energy).Considering the explained above, the conclusions of the calculations are that each converter is expected to increase the air temperature 20/30 = 0,67 °C during its operation.

The air flow rate is then defined by the equation:

$$P = Q.C_p.\Delta T$$

$$Q = \frac{P}{C_p.\Delta T}$$

Q: mass flow rate [kg/s]

P: losses [W] or [J/s]

Cp: thermal capacitance [J/kg.°C]

ΔT: fluid temperature elevation

The flow rate extracted from calculations generates a pressure drop which would require the use of large, noisy and expensive fans if the converters were cooled in series. Therefore, the proposed design considers two groups in parallel of fifteen converters in serial. In each group of fifteen converters, the expected air temperature elevation is 20/15 = 1,33 °C. The air flow rate is divided by 2 while the number of converters is as well divided by two. That results in an important pressure drop reduction respect to the serial configuration (see figure 18).

Once the cooling circuit configuration was defined, it was required to validate that the preselected heat sink was appropriate to guarantee the suppliers' thermal requirements. VEDECOM did a full set of simulations to balance efficiency with pressure drop. Results are shown below:

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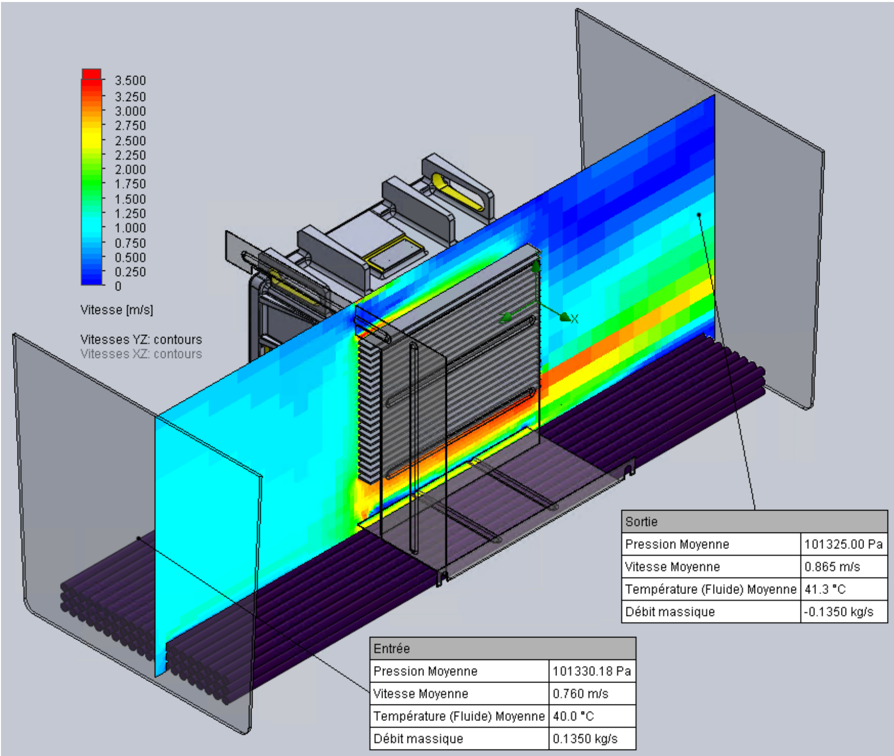

Figure 16 : air flow simulation (velocities)

After optimization, the obtained pressure drop is close to 5 Pa per converter, meaning 75 Pa for each group of fifteen converters.

Temperature distribution of the surfaces of the module are shown in figure 17:

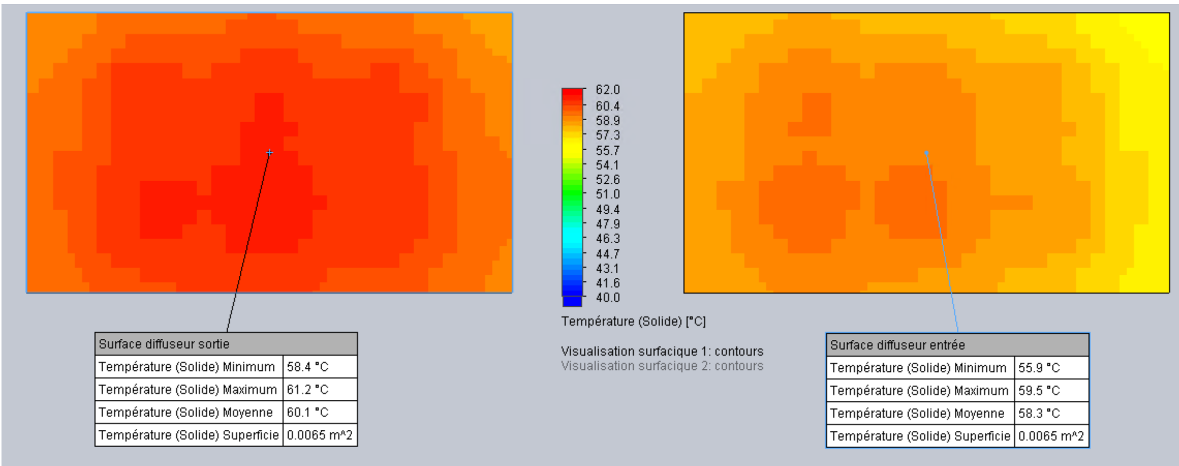

Figure 17 : temperature distribution

The maximum temperature expected in the first converter surface is 61.2 °C therefore, for the fifteenth converter the maximum temperature is estimated at 79.4 °C, which is below the maximum temperature specification, 90ºC. This analysis confirms the selection of the heat sink.

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3.2.2.2.2 Fan selection

To select the adapted fan, it is required to estimate the implementation on the road and sidewalks of the converters and the piping system. Once the pressure drop of each group of converters has been calculated, it is possible to calculate pressure drop of the supplying pipes.

VEDECOM used two methods to reach this objective:

- Analytical equations for linear pressure drops
- 3D simulations for all sections having multiple turns

The equations used in the first method are included below:

$$\frac{\Delta E}{L} = \frac{\lambda}{D} \times E_{Kin}$$

$\frac{\Delta E}{L}$: linear pressure loss [Pa/m]

λ : pressure loss coefficient

D : pipe diameter (m)

E_{Kin}: volumetric Kinetic energy of the flow [Pa]

$$E_{Kin} = \frac{\rho \times V^2}{2}$$

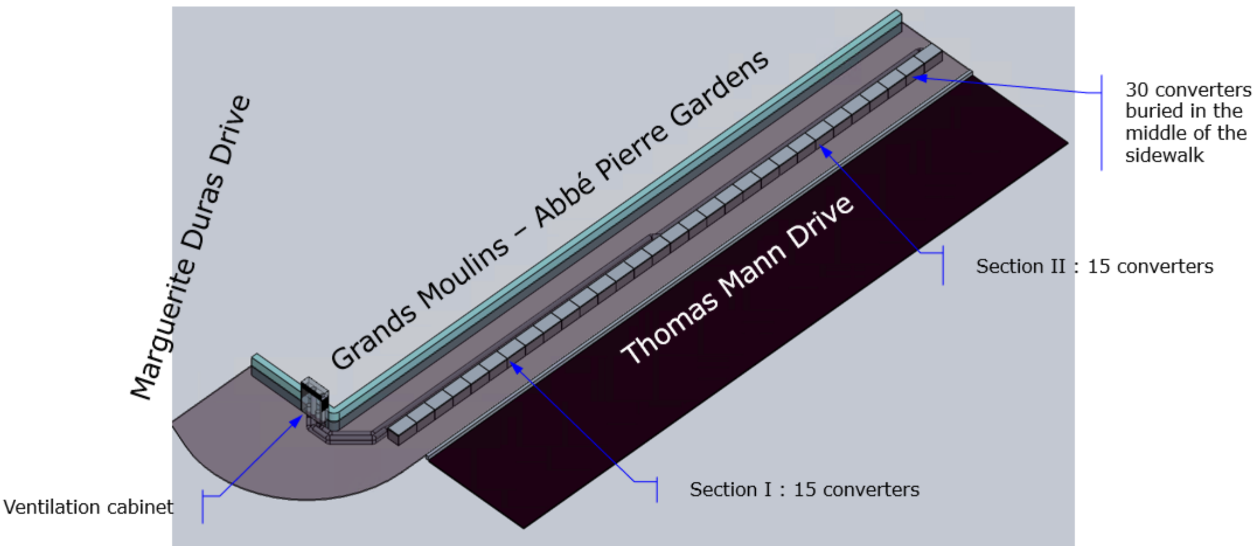
ρ : volumic mass [kg/m^3]

V : speed [m/s]

Blasius Formula for smooth pipes and Reynolds Number below 10^5:

$$\lambda = 0.316 \times Re^{-0.25}$$

Below VEDECOM proposed a worst-case setup for the experimentation located in Paris.



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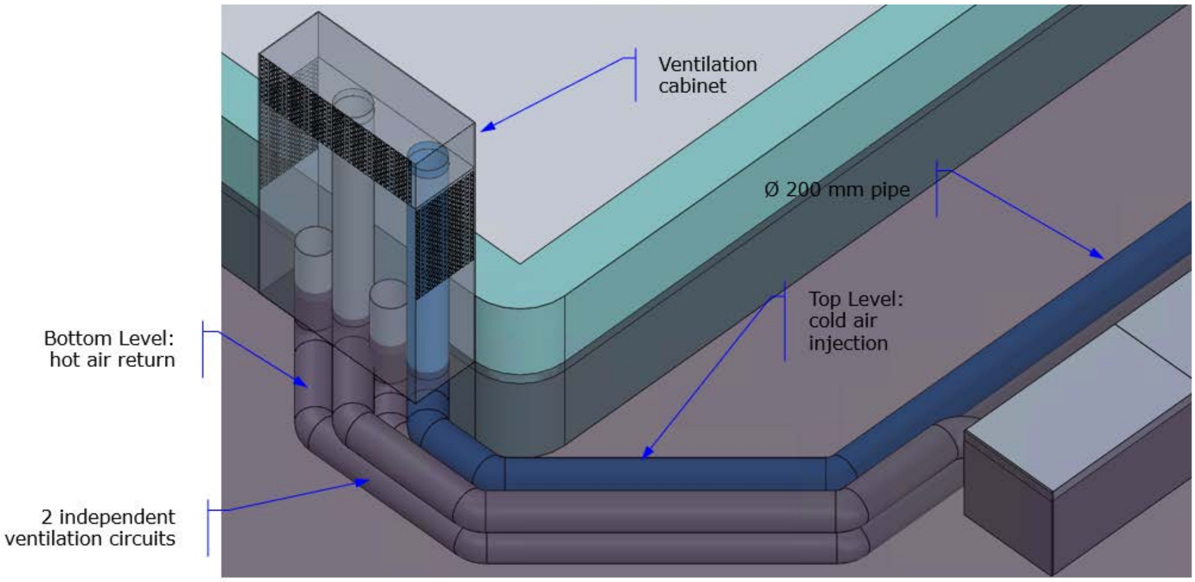

Figure 18 : blueprint of air ducts

Figure 19 : Velocities distribution

As an example, results obtained by simulations for one set of turns is showed below:

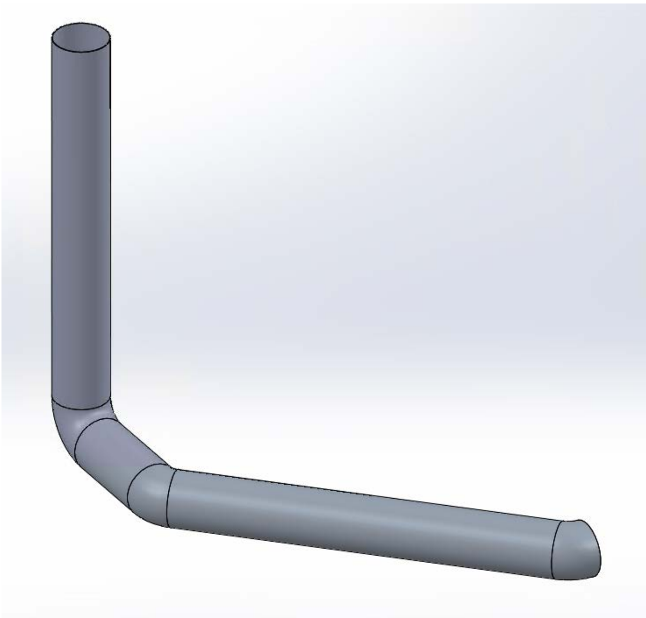

Figure 20 : CAD model

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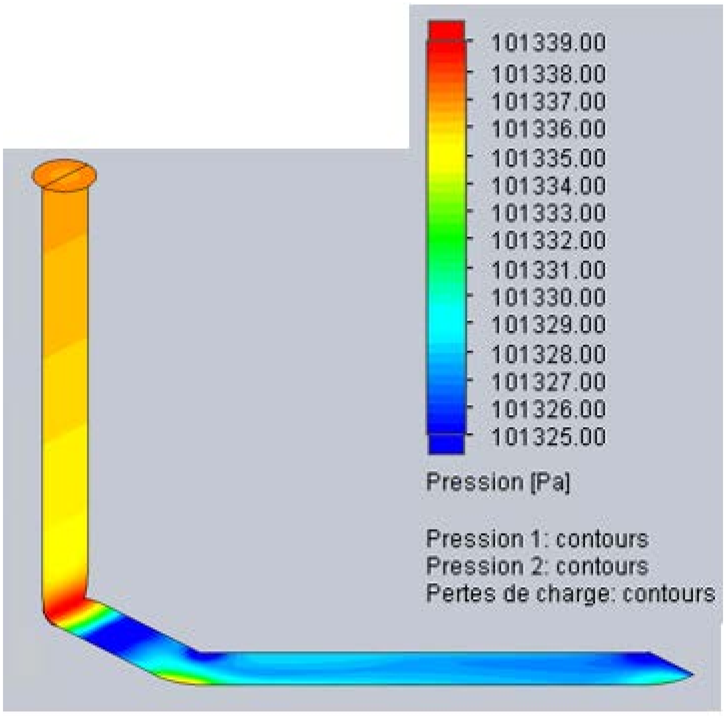

Figure 1 - Pressure distribution

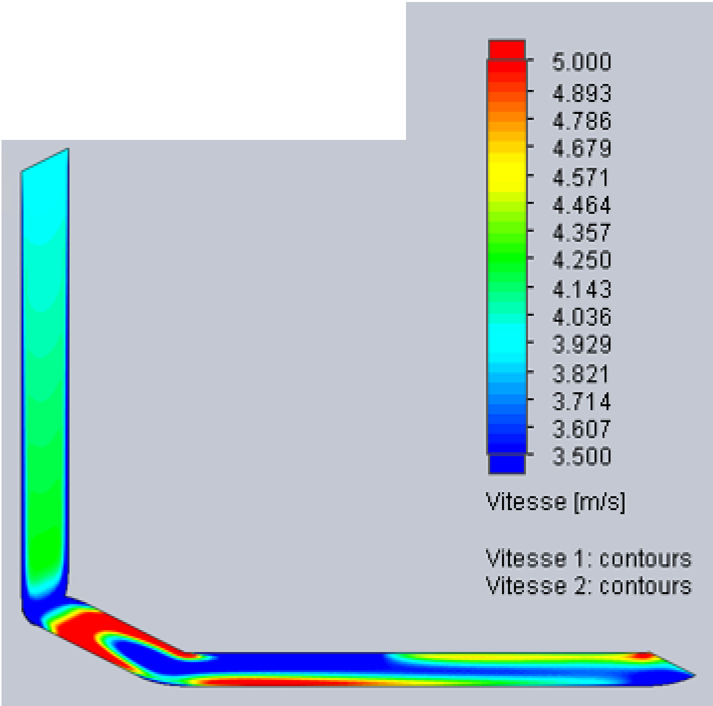

Figure 2 - Velocities distribution

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Cabinet connection intake			14 Pa
Pressure linear losses intake	0,98 Pa/m	18 m	18 Pa
Gutter connection intake			4 Pa
Gutter pressure drop	5,00 Pa/converler	15 converlers	75 Pa
Gutter connection outtake			4 Pa
Pressure linear losses outtake	0,98 Pa/m	32 m	31 Pa
Cabinet connection outtake			14 Pa

Total :	**160 Pa**

Figure 21 : pressure drops summary

The main conclusion of the pressure simulations is that, without considering the cabinet inlet and outlet, the maximum pressure drop is 160 Pa. From this value can be concluded that the fans must provide an air flow of at least 431 m^3/hour. The model showed below was selected not only considering its specifications, but also its short delivery time:

Figure 22 : Fan backup solution

Axial fan San Ace 9HV Sanyo Denki 48 V DC, 966m³/h, 172 x 150 x 51mm.

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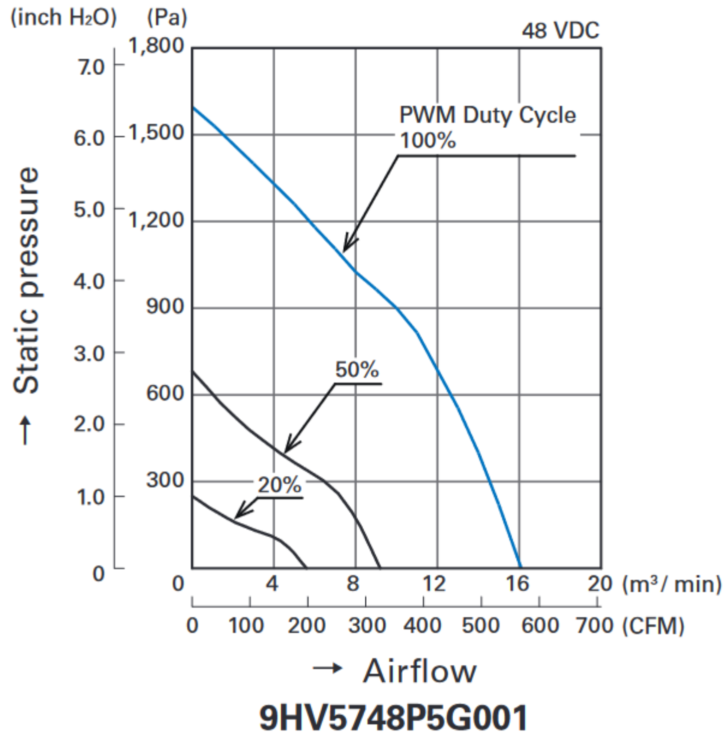

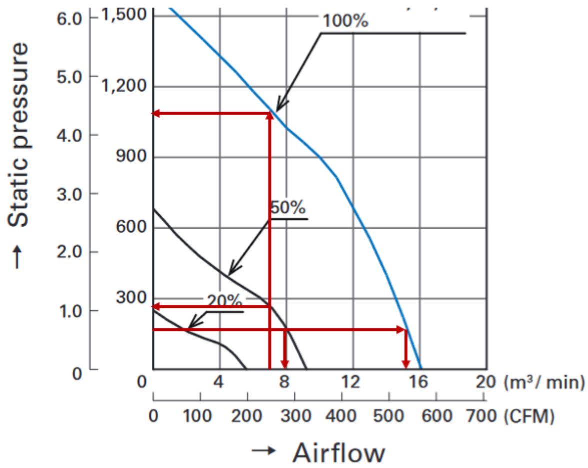

Figure 23 : fan curves and working points

The important margin of air flow provided by this model reduces the risk related with the fact that the venting cabinet is still not fully designed. This fan will as well allow to implement filters if required.

In order to reduce the expected noise considering that the available fan is too powerful, a temperature regulation system is added:

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Figure 24 : Temperature regulation

Fan speed control system for PWM fans: Sanyo Denki San Ace PWM controller 9PC8666X Series.

It has been defined to use one controller for the two fans, each fan will force the air flow of one of the two groups of converters. The controller will measure the air output temperature of these two groups.

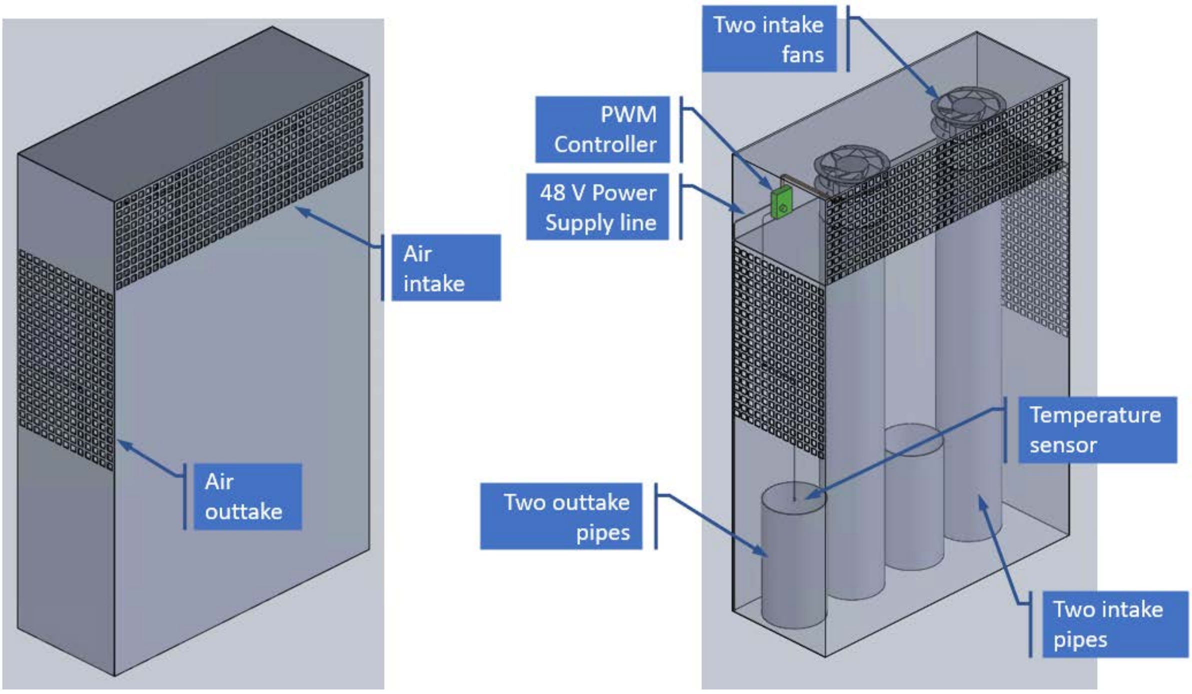

Figure 3 - Ventilation unit

The AC/DC converter cooling system is integrated in the selected cabinet.

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3.2.2.3 Car's equipment cooling.

3 cars will be equipped with the same coils and power electronic system:

- 1 Stellantis DS3
- 1 Renault Zoe
- 1 Renault Master

This situation motivates the use of the same cooling solution. Stellantis, Renault and VEDECOM agreed on using a liquid loop to extract the heat from the power electronic components to the air surrounding the cars.

The power electronic system is composed of 1 rectifier and 1 charger. These two elements are based on the same electronic circuit, however the working conditions are different and the expected power losses are different for each of them.

The Bill Of Materials (BOM) regarding the car's cooling circuit includes:

- 2 Liquid Cold Plates (LCP), one for the rectifier and one for the charger
- 1 pump
- 1 expansion tank
- 1 liquid to air heat exchanger
- 1 fan for the heat exchanger
- 1 set of liquid pipes

Most selected components are standard, only the set of pipes and the LCP are going to be built specifically for this experiment.

The main task for VEDECOM is to specify the LCP considering all the constraints.

Of course, this LCP must be able to extract the heat generated by the rectifier and the charger. The liquid flow to consider corresponds to the pump output pressure.

It was decided in agreement with the suppliers that the two LCPs will be connected in series, therefore the same flow rate will go through the LCPs.

he calculation of the liquid flow rate was made for two components of the BOM: the heat exchanger and the LCP. Notice that then lowest flow rate obtained from these calculations must be considered.

The main parameter is of course heat losses:

- Concerning the LCP, we have as well to consider heat density and maximum temperature difference allowed between the two power modules included inside rectifier and charger.
- Concerning the liquid to air heat exchanger, liquid flow rate is defined first by temperature difference between the liquid and the air and second by the air flow rate.

No specification was provided to define the air flow rate. Therefore, VEDECOM considered the criterium of extracting the total losses (1 800 W) at the speed of 11 km/hour (3 m/s). When the car is moving at lower speed, a fan must supply the same air flow rate. After analyzing pressure drop curves of liquid to air heat exchanger and fan performance curves, VEDECOM proposed the fan SPAL ref. VA14-AP11-/C-34A.

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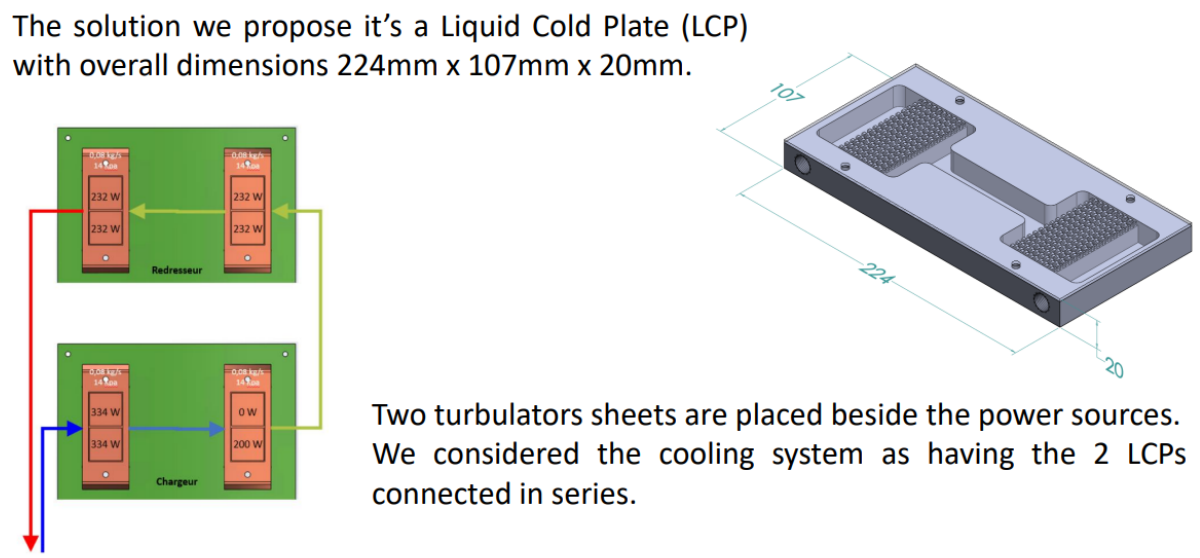
Figure 25 : Fan : SPAL ref. VA14-AP11-/C-34A.

Stellantis and Renault proposed two models of heat exchanger. Stellantis solution is larger and slightly more efficient, Renault solution is smaller and therefore easier to implement inside the Zoe prototype. VEDECOM considered the two models

Considering all these constraints, VEDECOM generated a specification sent to 2 different suppliers, this document exists only in French: “2022-03-30_Spécification_plaque à eau glycolée_v2.1”

The best offer was made by the BOYD Corporation, settled in Italy:

Following pictures are ©Boyd Corporation



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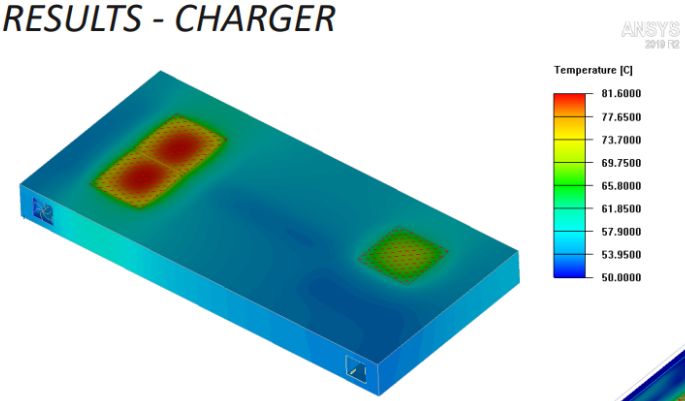
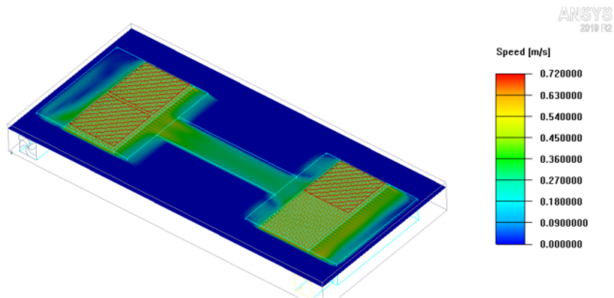
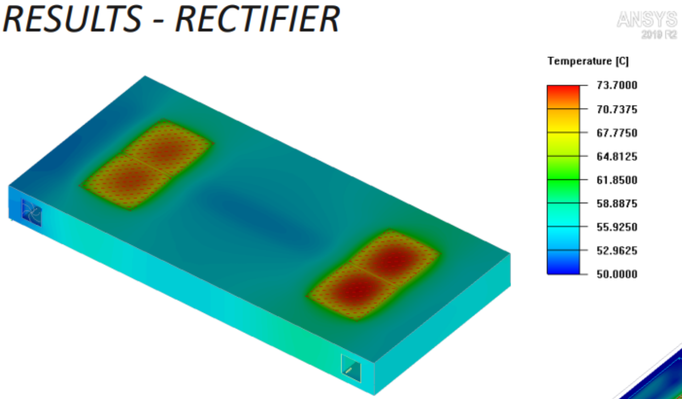
RESULTS - CHARGER

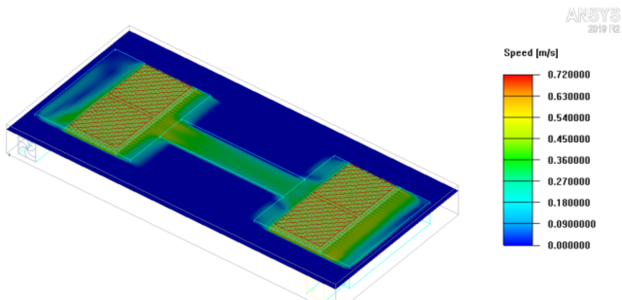




PRESSURE DROP: 2,5kPa

RESULTS - RECTIFIER





PRESSURE DROP: 2,5kPa

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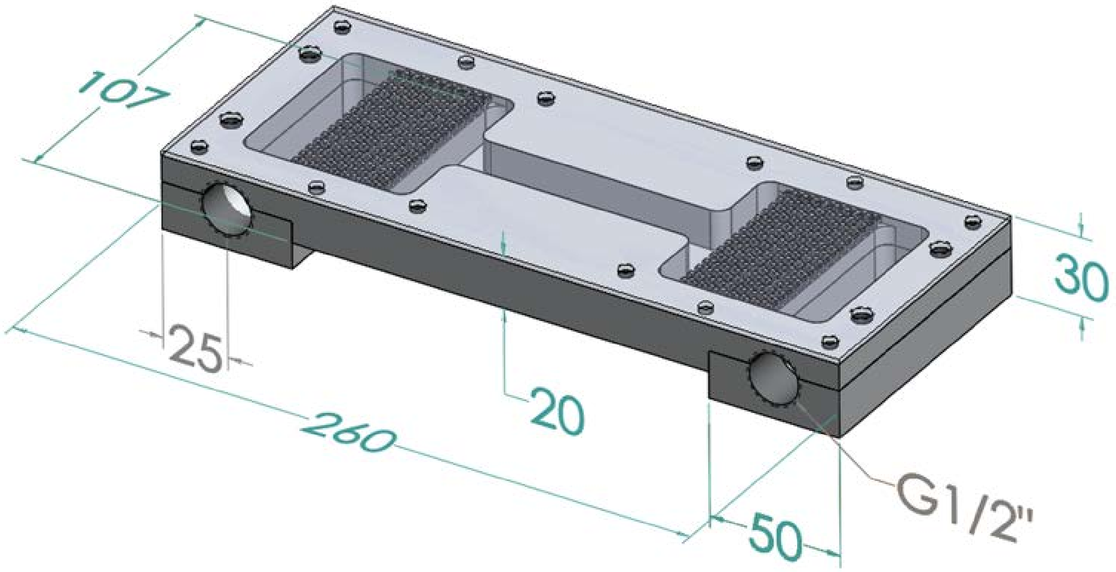

Pressure drop obtained by simulations is clearly below the maximum pressure drop allowed by the specifications. Therefore, even if the final model differs from this simulation a high margin is expected and mechanical modifications could be included without compromising the cooling system performance.

3.3 UCX Expected data to be collected

Showcase the information to be collected. This will feed the KPIs

Component	Quantity	Comments	Unity
Electromagnetic Field	The magnetic induction inside the vehicle		[µT]
	The magnetic induction around the vehicle		[µT]
Weather conditions	Temperature	Ambient / Air temperature	[C°]
		Road temperature Optic fiber	[C°]
		Power Electronics' temperature	[C°]

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	Precipitation / rain		
Electrical	AC/DC	input voltage	[V]
		input current	[A]
		output voltage	[V]
		output current	[A]
		efficiency	%
	DC/AC (DWPT frequency)	input voltage	[V]
		input current	[A]
		output voltage	[V]
		output current	[A]
		efficiency	%
		Frequency	[Hz]
	AC/DC	input voltage	[V]
		input current	[A]
		output voltage	[V]
		output current	[A]
		efficiency	%
	DC/DC	input voltage	[V]
		input current	[A]
		output voltage	[V]
		output current	[A]
		efficiency	%
Other	Charging time	Vehicle over transmitting track	[s]
		Transferred energy	[kW/h]

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		All system efficiency	%
	Vehicle data	Speed	[km/h]
		Traffic Data	[vehicles/day]
		Misalignment rate	%

3.3.1 Specific Power supply Instrumentation

3.3.1.1 PLC test Materials

Sniffer PLC G3		The equipment allows the observation of the G3 PLC frames exchange between all the Linky equipment
VNA and Signal Analyzer		Will be used to measure the impedance of the linky smart grid
Picoscope/ Signal Analyzer		Will be used to measure the noises signal

3.3.1.2 Power Line Communication

The aim of this tests is to measure the PLC G3 communication quality between the date concentrator and the meters. The tests will take place in two parts:

- Off-load tests:

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These tests aim to characterise the transmission channel of the PLT signal.

Test number	Actions	Description
1	Measurement of the line impedance in the transformer station	Measure the line impedance with a VNA (vector network analyser).
2	Signal measurement at the transformer station	Measurement with a spectrum analyser of the background noise in the CENELC-A band that naturally propagates in the power grid cables.
3	Measurement of the line impedance in the C4 electrical cabinet	Measure the line impedance via with a VNA (vector network analyser).
4	Signal noises measurement at the C4 electrical cabinet	Measurement of the background noise in the CENELC-A band that naturally propagates in the power grid cables with a spectrum analyser.

Linky PLC-G3 functional tests

Test number	Actions	Description
5	Generate PLC traffic between the K and the nearest meters at the C4 electrical box	The aim is to evaluate the PLC communication rate, the line quality indicator (LQI), the adaptive modulation types and the Tonmap. In order to simulate a daily data collection, a 120 bytes data size will be chosen. This will correspond to the average size of the data exchanged during a daily collection.

- On-load tests:

These tests aim to characterise the transmission channel of the PLT signal

Test number	Actions	Description
6	Measurement of the line impedance in the transformer station	Measure the line impedance with a VNA (vector network analyser).
7	Signal measurement at the transformer station	Measurement with a spectrum analyser of the background noise in the CENELC-A band that naturally propagates in the power grid cables.
8	Measurement of the line impedance in the C4 electrical cabinet	Measure the line impedance via with a VNA (vector network analyser).
9	Signal noises measurement at the C4 electrical cabinet	Measurement of the background noise in the CENELC-A band that naturally propagates in the power grid cables with a spectrum analyser.

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Linky PLC-G3 functional tests

Test number	Actions	Description
10	Generate PLC traffic between the K and the nearest meters at the C4 electrical box	The aim is to evaluate the PLC communication rate, the line quality indicator (LQI), the adaptive modulation types and the Tonmap. In order to simulate a daily data collection, a 120 bytes data size will be chosen This will corresponds to the average size of the data exchanged during a daily collection.

3.3.1.3 Electric Power Quality

The power quality analysers will be connected at the point of connection to the public grid.

Two types of measurements will be done. The first equipment will be connected into the cabinet, on the smart meter and will allow to measure electrical values and power quality measurements.

Measurements type 1:

- **Device:** ALPTEC 3000 Power Quality analyzer
- **Means:** Three-phase voltage / current measurements (sampling frequency = 10,2 kHz).
- **Period:** several weeks / months
- **Acquisition step:** 3s
- **Remote reading:** Yes
- **Analysis of data:**
  - Active and reactive power (load curves)
  - Harmonics: Individual harmonic levels up to order 51 and THD level
  - Flicker
  - Voltage sags

The following figure shows the schematic diagram of the instrumentation:

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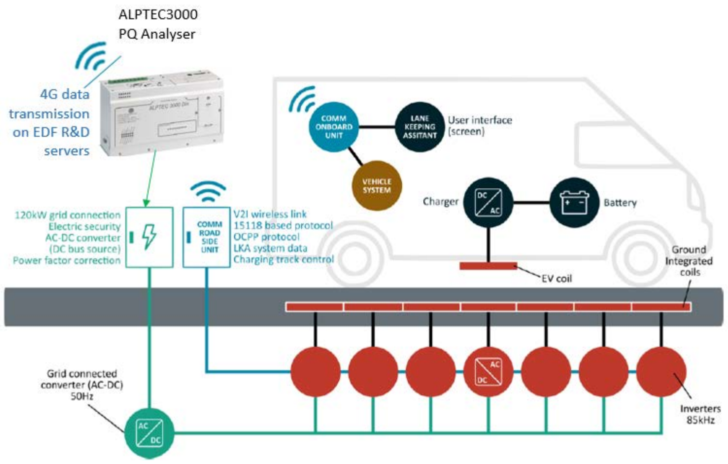

Figure 26 : schematic diagram of the instrumentation

The second equipment will be connected on the dedicated power line of the low power distribution station and will allow to take Supraharmonic (2 – 150 kHz) and DC leaks measurements. Depending on the technical specifications, the instrumentation could be moved into the cabinet (on breaker or smart meter).

Measurements type 2:

- **Device:** Specific power quality device developed by EDF R&D
- **Means:** Three-phase voltages / currents measurements (sampling frequency up to 1MHz)
- **Period:** 2 or 3 days
- **Acquisition step:** 200ms
- **Remote reading:** Yes
- **Analysis of data:**
    - Supraharmonic currents and voltages to study the impact of the charging equipment on PLC communications
    - DC current leaks analysis

The following figure shows the schematic diagram of the instrumentation:

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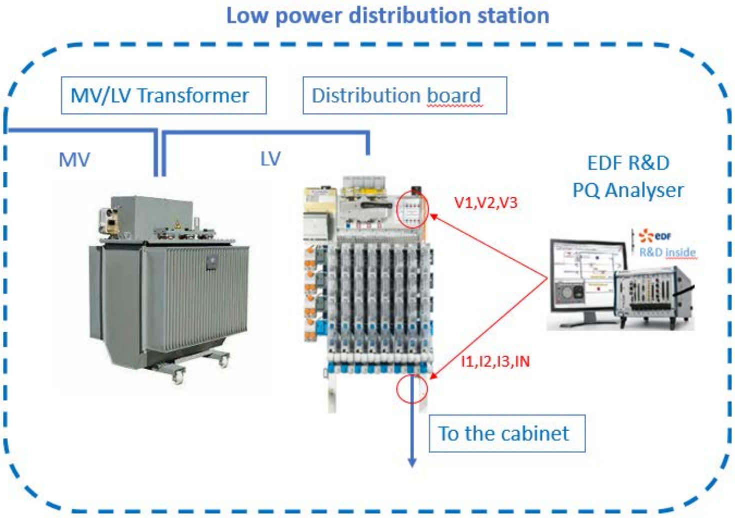

Figure 27 : schematic diagram of the instrumentation

3.4 UC2 Innovation

In this project, several versions of coils and power electronics were used. These different versions have made it possible to mature all the inductive charging technology. Also, extensive studies have been carried out on the integration of these coils. Thus, and in urban areas, they made it possible to assess the impact of this type of system on the roadway in terms of mechanical and thermal resistance.

On the other hand, this project also makes it possible to integrate these innovative solutions into life-size vehicles where we have been able to equip three different vehicles from two different car manufacturers.The efficiency of the DWPT has been assessed in laboratory, and has to be evaluated in real conditions.

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4 CONCLUSIONS

The UC2 experimentation will quantify the efficiency of dynamic wireless power transfer in a street at Paris, where vehicles drive at low speed (up to 30 km/h) or are stopped when the traffic light is red.

The installation consists of 30 coils (each 102 cm long) embedded inside the base coat of the road, powered by 30 inverters located inside a technical channel, embedded under the pavement (sidewalk), themselves being powered and controlled by a power supply unit.

The demonstration will take place at rue Thomas Mann (Paris), on one side of the road, along Jardin des Grands Moulins.

Three different vehicles will be adapted to be charged on the wireless charging lane: a Renault Zoe, a Stellantis DS3 and a Renault Master; in the Zoe and DS3 vehicles will be attached just one coil for a nominal power of 30kW. The Master will include three coils to be charged at 90kW

The same vehicles will be used in the other inductive demonstrators of INCIT-EV project.

The following elements have been addressed:

- The choice of an appropriate pavement structure, and a method of installation of the charging coils in the pavement structure
- The design of the coils, embedded inside the asphalt pavement
- The design of the inverters, that drive the coils and its cooling.

The whole system will be installed by end of 2022, and the charging efficiency will be measured in the following months, in various weather and temperature conditions.

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