D3.5: Report on user centric EV charging infrastructure.

Date of document – 12/2020 (M12)

D3.5: Report on user centric EV charging infrastructure.

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Technical References

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[1] PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

Document history

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V	Date	Beneficiary partner(s)
1	12/12/2020	First document by CIRCE
2	17/12/2020	Final document and review by coordinator

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Table of content

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List of tables

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List of figures

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0 EXECUTIVE SUMMARY

This document is the deliverable **“D3.5 – Report on user centric EV charging infrastructure”** of the H2020 project INCIT-EV (project reference: 875683).

The main objective of this deliverable is to summarize the developments of WP3 task. This deliverable will be made public the general information of the reference charging solutions designed.

The first 8 months of the development of the following task will be describe and summarize:

- Task 3.1 Cost-effective low and medium Power DC-DC bidirectional chargers (M4-M24)
- Task 3.2 Superfast conductive charging systems improvements (M4-M24)
- Task 3.3 Opportunity Wireless Power Transfer. Stops and Static en-route charging (M4-M24)
- Task 3.4 Dynamic Wireless Power Transfer. Urban and extra-urban charging (M4-M24).

“D3.10 – Update on user centric EV charging infrastructure” will update on the information collected in this document. This document will be delivered by the end of 2021.

The delivery of this deliverable is done in accordance with the description in the Grant Agreement Annex 1 Part A with no time deviation and no content deviation from the original planning.

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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:

- Smart and bi-directional charging optimized at different aggregation levels.
- Dynamic wireless charging lane in urban areas
- Dynamic wireless charging for long distances (e-road prototype for TEN-T corridors))
- Low power DC bidirectional charging infrastructure for EVs, including two-wheelers.
- Opportunity wireless charging for taxi queue lanes in airports and central stations

1.1 WP3 contribution to INCIT-EV objectives

The WP3 "User Centric charging solutions" of the INCIT-EV project has the objective of design and model the innovative charging equipment required to perform the rest of the project activities. The impact of this solutions will be evaluate associating them to a set of indicators which will feed the DSS libraries:

Besides this work package has a series of specific objectives:

- To establish and model the basics and functionalities of general charging solutions that will be used in each Demo areas use cases which will be demonstrated during the project.
- Adapt these reference solutions to the specifications of demo-sites.
- Carry out an evaluation of the innovative solutions and their potential impacts to feed the project library
- To assess the scalability, reliability and interoperability of the solutions that will be deployed in the Demo site areas.
- Considering the rest of the information generated by the rest of the WPs, be able to carry out an iterative validation loop phase for every task. This phase is planned to be complete the next 12 months.

This deliverable D3.5 will address the completion of all these objectives and feed the DSS tool.

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2 LOW AND MEDIUM POWER CHARGERS MODELS.

Within WP3 "User Centric charging solutions" of the INCIT-EV project, Task 3.1 has the following objectives:

- To establish and model the basics and functionalities of the Cost-effective low and medium Power DC-DC bidirectional chargers' solutions.
- Adapt these reference solutions to the specifications of demo-sites.
- Carry out an evaluation of the innovative solutions and their potential impacts to feed the project library
- To assess the scalability, reliability and interoperability of the solutions that will be deployed in the Demo site areas.
- Define a set of indicators associated with the task so that they can feed the DSS library.

This deliverable summarizes the development of task 3.1 and addresses the completion of objectives at M12.

2.1 Task development

Up to M12 of INCIT-EV project in task 3.1, general requirements have been studied, those regarding charging modes, plug types and V2G bidirectional DC charging.

For plug types, the work has focused on CHAdeMO and CSS standards and V2G Bidirectional DC charging requirements study reflects that the system should be compatible with ISO/IEC 15118 and CHAdeMO standard.

Due to the characteristics of the system, interoperability has been studied. This studied let us find the low and medium power charging system's interoperability solutions; Being the most important areas of work, the Aggregator, the physical charging interface, and communications.

The state-of-the-Art topologies for AC/DC, DC/DC bidirectional, and low power DC/DC stages have been described and compared.

From this comparison and its conclusions, a 50kW 24kHz AC/DC four legs multilevel with a very high-quality grid wave (THD<1%) independent control of each phase has been designed, and its specifications have been described. In the same way, a 50kW 85kHz DC/DC Bidirectional converter has been designed that allows the use of CHAdeMO and CSS standards to use and evaluate. Both systems, AC/DC and DC/DC, has been designed using SiC components and methodologies, in order to reduce their size.

Finally, a low power DC/DC charger system for two wheels vehicles has been designed to.

The low and medium power chargers' model architecture looks like the following figure.

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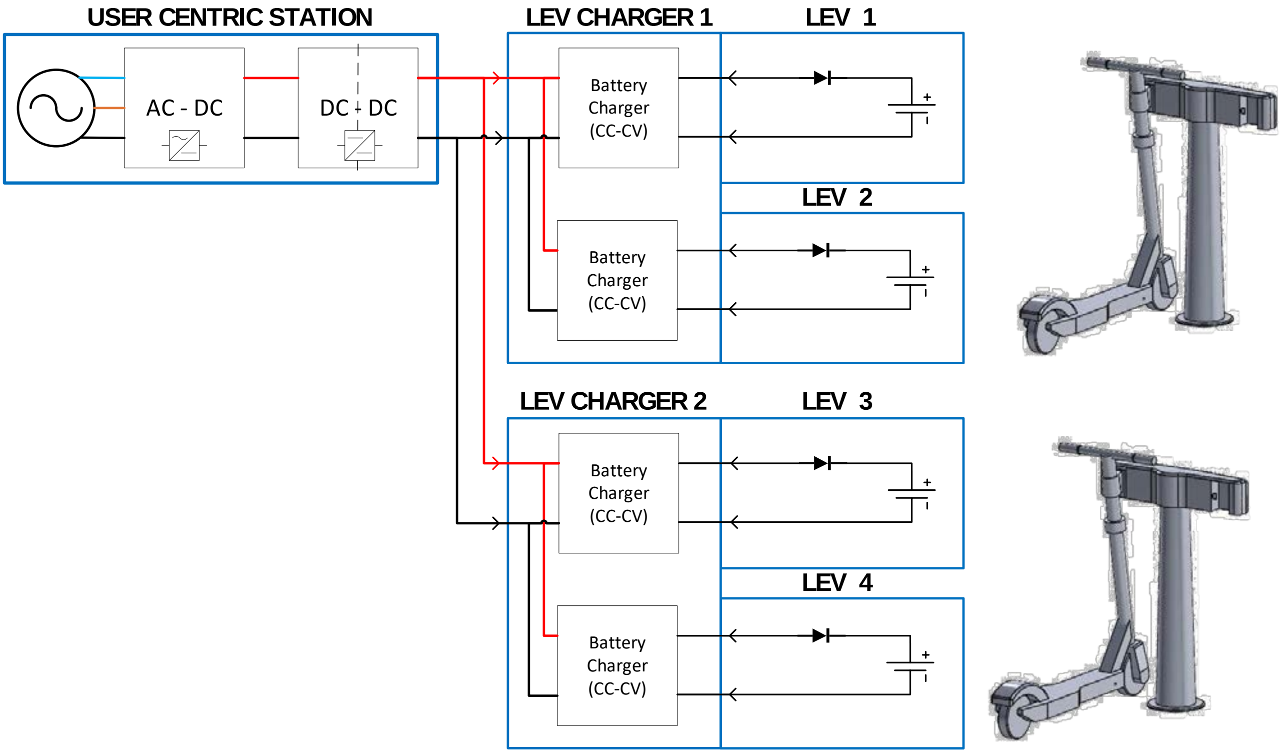

Figure 1: Two wheels vehicles charging system architecture

2.2 Task Conclusions

From this firsts month of task 3.1 the requirements to accomplish in the final system has been depicted. The main standards to be considered in the design to agree with normative has been studied. Also, the first version of the interoperability parameters and characteristics has been presented.

The state of the art of the Power electronic topologies to be considered in the design of each sub-system was reviewed. This study results in all the designs in this first stage of the project.

However, to definitively define the specifications and get the final design of the system, the following task should be performed in next months of task development:

- Analysis of the refrigeration of the solution
- Scalability of the solution and reliability.
- At least, an iterative validation loop phase will be executed

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3 SUPERFAST CONDUCTIVE REFERENCE CHARGERS MODELS.

Within WP3 "User Centric charging solutions" of the INCIT-EV project, Task 3.2 has the following objectives:

- To establish and model the basics and functionalities of the SFC DC V2G chargers' solutions.
- Adapt these reference solutions to the specifications of demo-sites.
- Carry out an evaluation of the innovative solutions and their potential impacts to feed the project library
- To assess the scalability, reliability and interoperability of the solutions that will be deployed in the Demo site areas.
- Define a set of indicators associated with the task so that they can feed the DSS library.

This deliverable summarizes the development of task 3.2 and addresses the completion of objectives at M12.

3.1 Task development.

The main SFC system functional specifications will be based on:

Up to M12 of INCIT-EV project in task 3.1, general requirements and interoperability have been studied. Considering the major requirements, to minimize the charging time for long-distance, to develop a user-friendly interface and to develop a scalable charging network.

Regarding interoperability, the most important aspect to the Super-Fast Conductive system is its interoperability with all the actors it interfaces. Such as the GRID and GRID Operator,

the vehicle and user, and the vehicle and user identification and payment. These interfaces and the solution's implementation have been studied, addressing in last one synergy between ICT platforms, due to issues regarding GRID and EV are standard.

Focusing in to minimize the charging time for long-distance, a 350kW 20kHz converter has been designed to us in Super-Fast Conductive charging station. The modular SiC components design it allows to achieve a power efficiency conversion above 97%, with an inconsequence size and unitary-cost reduction.

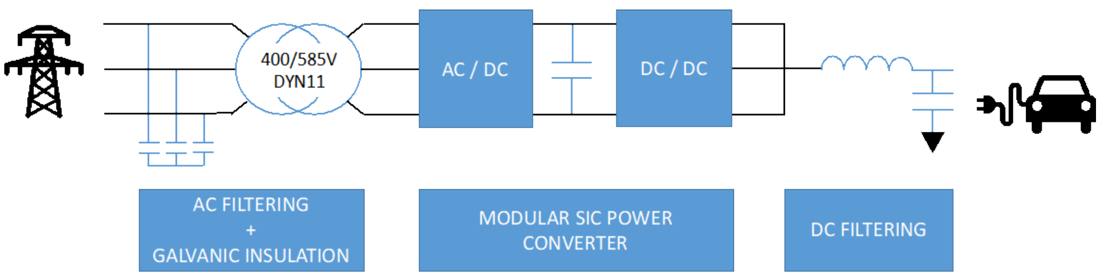

Figure 2 Full topology of a fast charger

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For the refrigeration system has been studied in two cases:

- A passive one uses a pump to circulate a liquid coolant into the charging cable with a certain flow rate. The hot liquid circulates through a liquid/air heat exchanger which is cooled down by forced air convection using to a fan.
- The active one, use a thermodynamic system to cool down the heat. It increases the electric consumption of the refrigeration system, but it has a better cooling capability.

Regarding the improvement of current protections, the main of they described in the IEC61851 For SFC system, several protections shall be implemented and improved, for the users and the hardware parts.

- The protection of the users consists of avoiding any direct and indirect contact with active parts that can present hazardous voltage.
- The protection of the hardware is used to prevent any short circuits or fire in the charger.

Designing work has been done, to accomplish and improve that procections mains and systems.

The most important work performs to develop the system has been to optimize the charger accessibility and the physical interface. Easiness to use has been consider, focusing in integrate cable management system. The cable management system design improves the user experience. Allows the user to connect his car easily, wherever the charging plug of the EV is located. Designed to balance the weight of the cable and avoid the cable touching the ground, thus minimizing wear and tear, the cable shall never touch the ground and is never in the way of the cars or the user, thus limiting wears and tears.

Finally, to deploy in the variety of needed location with different power supply constraints has been considered to make the Super-Fast Conductor system scalable. For this, the study of better grid integration has been done. An Energy Manage System with an algorithm computing the maximum power set-points of all connectors that compose a Charging Station, based on priority rules for the simultaneous charging sessions, has been considered to adjust the power delivery to the chargers to the current grid conditions. Besides this system could be communicated with the smart grid. Besides, low voltage feeders, 400V on three phases, has been consider as the current preferred and easiest way to mass install SFC systems.

3.2 Task Conclusion

All in all, the requirements are outlined to make an SFC system fast, user friendly and scalable, to be able to present a gas station like experience to the end user. This will greatly decrease the range anxiety of the typical EV user, thus further promoting electric transport vehicles, while enabling the scalable deployment of SFC systems.

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4 OWPT REFERENCE CHARGERS MODELS.

Within WP3 "User Centric charging solutions" of the INCIT-EV project, Task 3.3 has the following objectives:

- Design and model a OWPT solutions that will be later used to conform the Demo areas
- Carry out an evaluation of the innovative solutions and their potential impacts to feed the project library
- To assess the scalability, reliability and interoperability of the solutions that will be deployed in the Demo site areas.
- Define a set of indicators associated with the task so that they can feed the DSS library.

This deliverable summarizes the development of task 3.3 and addresses the completion of objectives at M12.

4.1 Task development

For the INCIT-EV project's task, 3.3 up to M12 general requirements have been studied. This study has been focused on different standards not only EMC standards but also all the standards related to opportunity wireless power transfer. Among other standards about communications, measure procedures, etc.

The dimensions of the 30kW secondary coil have been considering when general requirements have been studied, due to the necessary interoperability between this one and the primary new design coil. Besides the requirements of a 50kW secondary coil have been studied. In both cases, the vehicle interoperability ground clearance has been considered.

From lesson learned from Fabric project, general interoperability considerations, the validation method and the architecture have been designed, although is necessary to keep on studying these subjects in the next months.

The state-of-the-Art topologies for IPT (Inductive Power Transfer) system have been described and compared. From this comparison and its conclusions, a 50kW system interoperable with 30kW secondary coil has been designed. To perform the design of the system, traditional road integration with 5 cm min below the road surface has been considered for the coils. And FEM (finite element method), moreover analysis, have been used to model the system inductor.

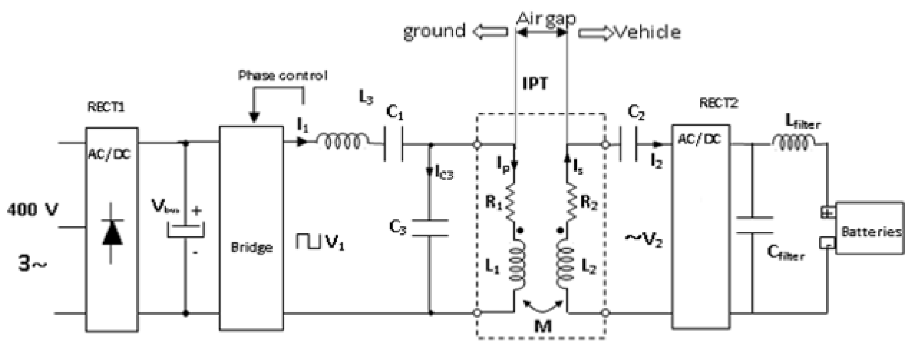

Figure 3: 50 kW topology

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Also, the state-of-the-Art topologies for power electronics stages have been described and compared. From this comparison and its conclusions, a 90kW 85kHz DC/DC Bidirectional converter has been designed that allows the use with the primary of IPT system previously design. This system has been designed using SiC components and specific methodologies, to reduce their size.

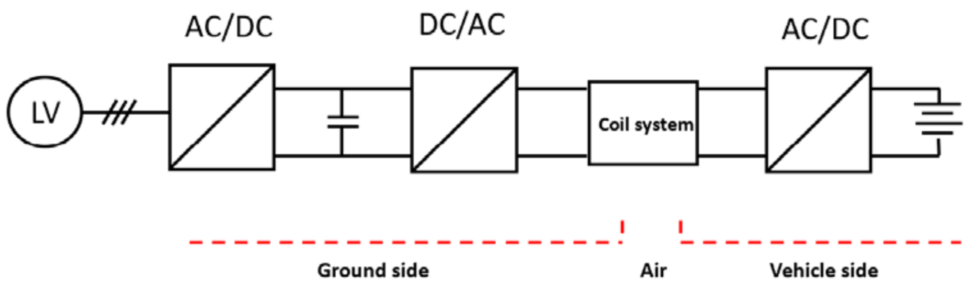

Figure 4 Power electronics stage representation

Finally, the study and modelling the different material for shielding the magnetic fields and study the magnetic field to pass the EMC test, have been performing, although is necessary to keep on studying these subjects in next months

4.2 Task Conclusions

These firsts month of task 3.3 the requirements to accomplish in the final system has been depicted. The main standards to be considered in the design has been studied. Also, the first version of the interoperability parameters and characteristics has been presented, and a brief description of lessons learned in Fabric project has been considering.

The state of the art of the Power electronic topologies to be considered in the design of each sub-system was reviewed. This study results in all the designs in this first stage of the project. Besides, an evaluation of the innovative solution and its potential impact was carried out.

However, to definitively define the specifications and get the final design of the system, is necessary to keep working in the following in the next months of task development:

- Data collection and measurements needs will be listed (car, infrastructure) so all information for related to charge actual performance can be extracted for further billing post-treatment.
- Study the magnetic field to pass the EMC test

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5 DWPT REFERENCE CHARGERS MODELS.

Within WP3 "User Centric charging solutions" of the INCIT-EV project, Task 3.4 has the following objectives:

- Design and model the general DWPT solutions that will be later used to conform the Demo areas
- Carry out an evaluation of the innovative solutions and their potential impacts to feed the project library
- To assess the scalability, reliability and interoperability of the solutions that will be deployed in the Demo site areas.
- Define a set of indicators associated with the task so that they can feed the DSS library.

This deliverable summarizes the development of task 3.4 and addresses the completion of objectives at M12.

5.1 Task development

For the INCIT-EV project task 3.4 up to month 12, the state of the art of the DWPT (Dynamic Wireless Power Transfer) systems have been backgrounded. A study of main progress expected beyond the state of the art has been performed. Besides standardization's state-of-the-art has been studied, focusing in the Static WPT standard (SAEJ 2954), the most recent version for EMF levels compliant, the EMF European Directive 2013/35/E, and IEC relevant standard for EMC. All this let address the general system, EMC, and EMF requirements for the urban and extra-urban uses cases.

From lesson learned from Fabric project, among other previous projects, general interoperability considerations, the validation method and the architecture have been designed. However, it is necessary to keep on studying these subjects in the next months.

Systems modelled considering interoperability among different vehicles, systems (Ground clearance will vary from 15 cm to 18 cm for the vehicle considered) and integrations (Traditional road integration with 5 cm minimum below road surface for the coils) have been the followings

- Urban primary system
- Inter and extra urban primary system
- On-Board system

Precise lateral localisation of the vehicle system has been depicted, from the point of view of been based on road markings and how to auto-calibrate the camera system with load feedback. This allows the accomplishing of a system to have a precise and robust estimation of the misalignment requirement. Besides, the necessity of a system to provide the driver with visual feedback on its actual alignment conditions, makes that a manual and automatic guidance system have been studied

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5.2 Task Conclusions

These firsts month of task 3.4 a list of projects around the world were reviewed in the state-of-the-art section followed by the technical research topics about the wireless chargers. The main standards and prospects were resumed, and the first version of the interoperability parameters was presented, including progress expected beyond the current state of the art.

Several systems to make part of urban and extra-urban DWPT system have been modelled and design. Requirements for the final DWPT system and the systems to vehicle localization and guidance has been studied and depicted.

However, to definitively define the specifications and get the final design of the system, is necessary to keep working in the following in the next months of task development:

- Data collection and measurements needs will be listed (car, infrastructure) so all information for related to charge actual performance can be extracted for further billing post-treatment.
- Study the magnetic field to ensure the EMC and an electromagnetic field safe for users.

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6 CONCLUSIONS

This document sums up the activities accomplish for the different task on work package 3 in the first year of INCIT-EV project.

Although most of the task has been fulfilled, it is necessary to keep working in some activities up to be totally complete, like the systems design and EMC or electromagnetic field issues.

Few activities are not started or slightly beginning. However, it is necessary to push tasks related to data collection and measurements due to the necessity to be listed (car, infrastructure) so all information for related to charge actual performance can be extracted for further billing post-treatment.

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