SEVENTH FRAMEWORK PROGRAMME

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PROJECT

PUBLISHABLE SUMMARY

FAST IN CHARGE

INNOVATIVE FAST INDUCTIVE CHARGING SOLUTIONS FOR ELECTRIC VEHICLES

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Executive summary

The FastInCharge project was a 3-year European FP7 project coordinated by Douaisienne de Basse Tension (DBT). The topic of the call was “Smart infrastructures and innovative services for electric vehicles in the urban grid and road environment” and 9 organisations from 6 different countries worked together to achieve that mission. The overall objective of FastInCharge was to foster the democratisation of electric vehicles in the urban environment by developing an easier and more comfortable charging solution which aimed to ease the Electric Vehicle (EV) use by the large public and facilitated their implementation in the urban grid.

The concept of FastInCharge was to create a highly performing inductive solution that enabled a 30kW specified DC power transfer to the vehicles in two charging operational situations. Indeed, the inductive technology developed was integrated into an electric vehicle and into two charging stations, one stationary and one on-route. The full functional chain has been carefully scrutinised in order to ensure an optimal, safe and sustainable solution.

The inductive power transfer development was led by the Technical University of Gabrovo (TUG), the EV performance and safety was ensured by the Centro Richerche Fiat SCPA (CRF), the communication between the EV and the charging station was led by Douaisienne de Basse Tension (DBT), the positioning of the charging device on the coils was directed by the Fundacion Tecnalia Research & Innovation (TECNALIA) and BATZ Sociedad Cooperativa (BATZ) and finally, the impact of inductive charging on the grid was studied by the Institute of Communication and Computer Systems (ICCS) that also developed an energy management system enabling the coordination of the charging network and offering several services to EV users. Automobilovy Klaster Zapadne Slovensko Zoruzenie (ACWS) was in charge of the communication around the project and the dissemination of the results and Euroquality (EQY) managed the project financial and administrative issues. The simulation of the integration of the FastInCharge solution has been enabled by the participation of the City of Douai (DOUAI), city partner of the project. The City of Douai (DOUAI) provided traffic information that was exploited by ICCS to estimate the demand of static and dynamic inductive chargers and analyse the integration of the FastInCharge solution in urban cities providing useful results on the potential network issues which may be raised due to the fast inductive charging deployment. These results served as guidelines during the actual implementation of the stations in the city of Douai, and enabled accurate and efficient troubleshooting. The results were also used to extrapolate the impact of the limited demonstration to a wider scale such as the whole city.

The proposed solutions demonstrated the enhanced attractiveness of electric mobility, both in terms of convenience and costs, while showing how they ensure a correct relationship with the electric supply network and its requirements, as well as the economics of the needed investments.

Summary description of the project context and the main objectives

Economic and environmental factors are the main drivers for the development of innovative solutions in the automobile industry and in the gradual transition to energy obtained from renewable energy sources. Indeed, it is now accepted that fossil fuels cannot be considered as the resource of the future for transportation due to the global warming and to the relative scarceness of the resources. In consequence, in the last decade, almost all leading automobile companies have contributed to research and development in the field of electric vehicles. As a result of this, the first effective and economically sound solutions are already in use in city traffic.

However, this success is fragile and a lot of problems are still to be resolved. One of the main widely discussed problems is the charging of electric vehicles with electrical energy. Two main aspects are associated with the challenges of charging electric vehicles – (1) battery capacity and mileage without charging, and (2) infrastructures and charging time. Indeed, the battery capacity, along with the performance of the vehicle, is directly linked with the range of the vehicle. The technologies available do not allow the EVs to have a range even close to the fossil fuel engine that we currently use. This is one of the main issues from the consumer's point of view, and one of the main reasons why EVs are not more popular among citizens. The infrastructures and charging time are other aspects of the same problem. The consumer is not willing to buy an EV if he is not sure that he can recharge it easily on his way, meaning that there are a lot of charging stations available everywhere, and relatively fast, meaning that it is out of question to wait 12 hours that the EV is finally charged for using it again.

Thus, a significant need exists to drastically improve the convenience and sustainability of electric car-based mobility. In particular, researches should focus on the development of smart infrastructures, and innovative solutions that will permit full EV integration in the urban road systems while facilitating evolution in customer acceptance.

Within this context, activities of the FastInCharge project were focused on investigation into an alternative and innovative fast charging solution making the charging process easier for the driver, minimising risks deriving from vandalism, and being able to be shared between a stationary and an on-route usage to increase the vehicle range while reducing the size of on-board energy storage systems. The development of an energy management system linked to this alternative and innovative charging infrastructure, which considers both the EV drivers' needs as well as the constraints that are set by the capacity of the existing grid infrastructure, has also been investigated during the project.

Therefore, the ambition of FastInCharge was to create a highly performing modular inductive fast charging solution, that enable a 30 kW power transfer to the vehicles, able to be used in the two charging operational situations mentioned above. A scrutiny of the full functional chain has been considered to ensure an optimal, safe and sustainable solution around: battery charging, EV performance and safety, EV range, communication between the EV and the charging station, connection of charging stations to the grid, development of an efficient energy management system, and intelligent coordinated systems.

In the scope of the project, achievement of a full-scale charging infrastructure has been considered in order to assess on one hand its technical feasibility and acceptance by the user as an alternative solution that could get rid of the autonomy and charging issue, and on the other hand to test and study its implementation and integration in the urban environment to foresee eventual problems that could occur in real-life conditions, considering also the optimisation of the energy of this new infrastructure and its interaction with the grid and vehicles.

Such an approach for this kind of charging infrastructure can greatly help cities and local authorities to deal with the investment problem linked with the integration of heavy cost infrastructures. The investment and the construction work can be distributed along the years and avoid huge one-shot investments. The modular approach allows to implement easier stationary and on-route charging solutions and also decreases the overall cost of the infrastructure, as it could rely on mass-production of shared elements.

Description of the main S & T results/foregrounds

1. Introduction/ System architecture

The R&D work conducted during the project was focussed on 1/ Charging station and inductive charging units able to deliver a power transfer of up to 30kW with an efficiency of up to 92% through a 10cm air gap between the primary coil located in the road and the secondary coil embedded in the vehicle, 2/ Electro-Mechanical unit on vehicle side to ensure that the distance between the two inductive plates remains constant in order to optimise the power transfer efficiency and to help the driver to position the vehicle using needed sensors, and 3/ Communication units using different communication interfaces to permit, for instance, to monitor the operation of the charging stations, to enable the remote control of the maximum charging rate of the stations, or to offer several services to the Electric Vehicles (EV) owners.

Rated output power	30kW
Air gap	80 mm ± 10mm
Misalignment	In direction X(L): ± 15cm In direction Y(W): ± 10cm
Rated efficiency	Above 90% (80% misaligned)
Dimensions of the primary coil	800x700x90mm
Dimensions of the secondary coil	800x700x60mm – 20/25Kg

Figure 1 - FastInCharge inductive charging main objectives

The different components that were developed during this project are presented in the following sections.

2. Contactless power module

In contactless power transfer systems, inductive methods are preferable and mostly used in practice in the last years. The core of this system is a specially designed transformer, called Inductive Power Transfer Module (IPTM), with an optimizable magnetic coupling due to the air gap between the transmitting and receiving coils. Important aspects in the electrical design of the Inductive Power Transfer Module (IPTM) are the dimensions of the transmitting and receiving parts, and the air gap between them. Contrary to the distance between the coils that is defined by the specific application of the IPTM, their geometrical dimensions are subject to optimisation and have great influence on the configuration of the equivalent circuit and the value of the equivalent inductances.

As a first step in the project, numerous computer simulations have been carried out to identify the most relevant design. The distribution of electromagnetic field in the areas around the coils has been analysed and, based on these simulations, level of influence of the electromagnetic field to the nearby objects has been determined, according to the International Commission on Non-Ionising Radiation Protection (ICNIRP) requirements.

Then, once the design of the IPTM has been defined following simulations and realized, an important work has been done around functional and performance tests, including work on shielding to both control the magnetic field distribution using aluminium shield and to protect the primary coil installed later on the ground by a cover made of non-magnetic material based finally on polymer concrete.

Figure 2 - Mock up for static and on-route inductive charging performance test and analysis

In the end, during the demonstration phase of FastInCharge solutions in real conditions, the design and parameters of developed IPTM module was validated in accordance with the main project objectives (as presented on Figure 1), showing contactless transfer of energy in static and dynamic mode at 35kW input power level and up to 9cm distance between the coils, specified efficiency of IPTM - close to 92% at a 30kW output power with no misalignment between the coils, safe electromagnetic field exposure, less than 27μT, in accordance with ICNIRP standard requirements, ability of peak overload of the system (up to +40%), which can be used at on route charging, and design and manufacture of reinforced concrete housing for the transmitting windings having the necessary strength, taking into account the real environment urban conditions.

Static charging	Active load No misalignment	Battery load No misalignment	Battery load 15cm misalignment
Station Input power (W)	34428	27749	26089
Output DC voltage (V)	392.3	353.9	348
Output DC current (A)	80.3	70.9	62
Output DC power (W)	31501	25113	21576
Efficiency (%)	91.5	90.5	82.7

Figure 3 – FastInCharge static inductive charging main results

On-route charging	Coil #1 Min misalign.	Coil #2 Min misalign.	Coil #3 Min misalign.	Coil #4 Min misalign.
Station Input power (W)	26179	26719	26179	26179
Output DC voltage (V)	349	352	352	349
Output DC current (A)	68	69	69	68
Output DC power (W)	23732	24288	24288	23732
Efficiency (%)	90,65	90,9	90,9	90,65

Figure 4 - FastInCharge on-route inductive charging main results

3. Power electronics in charging station (control system, power circuit…)

The main purpose of power electronics in charging station is to supply the transmitter coil of the IPTM with HF energy with specified voltage, frequency and power values. It ensures the maximum efficiency of transferred energy. The power electronics of the charging station contains input filter, main rectifier, HF inverter, and matching and compensation modules. The main aspect of development activities in the project was around the HF inverter which was designed for two operating modes – static and dynamic. The most important characteristic is the maximum power provided by the system - 30kW output power in continuous operating mode. To achieve dynamic charging mode, a special control system has been developed and designed. It contains two levels: inverter control system and charging station controller.

The inverter controller is a specially designed microprocessor system with several units which are 1/ IGBT Gate drivers, being dual channel and having the ability to manage dual transistor module, 2/ a control board that generates and maintains the inverter operating frequency by keeping a resonance in the equivalent high frequency (HF) inverter circuit, irrespective of load variations, 3/ IGBT control distribution board that is responsible for the distribution of pulses to each power transistor and for switching the windings in dynamic mode, and 4/ a control board that adjusts the switching of windings in dynamic mode and also determines start and stop signals.

The charging station controller is a higher level feature using standard commercial product. Through a Wi-Fi communication module, which is situated in both charging station and vehicle, the station controller receives in CAN format from the EV side information about the output Direct current and voltage of the secondary AC/DC electronics and the necessary battery current and voltage values. These information are compared and allow adjustment of the inverter operating mode. The charging station controller also has a monitoring function to process signals from different safety sensors, which protect primary power electronic modules and observe for correct Wi-Fi communication between charging station and EV’s secondary electronics.

The other elements of the charging station’s power electronics are the sets of matching transformers and capacitors for safety reasons (galvanic isolation), and matching between electrical parameters of HF inverter and IPTM.

4. Inductive charging station

The inductive charging station has been designed in a way to enable a simplicity of use by limiting user interfaces on the station allowing it to manage all the charging process and relevant information directly from the vehicle. The only visible information from the outside of the station is lighting to identify the status of the station: Red to indicate unavailability, green to indicate availability, and blue to indicate on-going charging process.

The design of the charging station has been chosen to minimize its footprint on the ground but keeping a good distance visibility, especially for the lightning status, making the station to be around 2 meter high. A dedicated cooling system coupled with temperature monitoring has been developed around the power electronics to ensure safe and long usage. A special attention has also been made around the maintenance accessibility and operations to be as easy as possible.

The physical interaction between the user and the charging system has been willingly limited to a tablet located in the vehicle. A new application has been developed for this tablet in order to keep the EV driver aware of the available charging station, and allowing communication and guidance through the charging process, supervision and management of this last, or access to advanced information and configuration settings.

In the end, dynamic and static charging stations have been implemented in the City Of Douai (FRANCE). The dynamic charging station has been installed at a city crossroad, and the static charging station has been installed at the municipality workshop. For the dynamic charging station, a dedicated electrical control cabinet with a power of 42kVA has been installed, for which ERDF (Electricité Réseau De France), a partner of DOUAI, realized the electrical connection to the power supply. For the static charging station, electrical connection has directly been realized on the terminals of the low voltage switchboard of the municipality existing building.

Dynamic charging station’s equipment’s, with primary plates, were implemented in respect to an execution plan. Infrastructures works were done in the same time, with pipes and electrical connections (power cables of the coils, thermal protection and magnetic sensor). All the work done has allowed to perform all the needed conformance and performance tests under real usage conditions, as well as the demonstration of the project result during an Open Day.

Figure 5 & 6 – Ongoing installation work and view of the finalized installation

5. Electro-mechanical system specific for inductive charging on vehicle side

The secondary coil of the inductive charging system was integrated in the lower part of the vehicle with the secondary AC/DC module, and positioned near the primary coil in the ground. It can be said that the object of the pick-up positioning system is also to provide a method for fast inductive charging technology, so that it can be achieved more flexibly and efficiently. This system considered the automotive general requirements for systems and parts, which means: design to cost, lightweight, compliant with automotive standards for functionality, compliant with automotive standards for safety, suitable for large-scale productions, adaptable to different versions of models, easy to integrate into the vehicle, noise & vibration compliant, sensorized and connected to the vehicle, crashworthiness and simulation assessment.

A specific system was obtained in order to ensure the efficiency of inductive charging operations for static and on-route operation of the electric vehicles. The system has been adapted to the particular requirements of the demo vehicle, a light commercial vehicle (Iveco Daily). Nevertheless, the concept can also be adapted to any other kind of vehicles with different requirements.

The main goal for the pick-up positioning system is to approach the onboard installed coil to the primary coil, which is buried under the ground. It allows a vertical shift that permits to achieve the appropriate distance between the two coils. Thus, the distance between coils is ensured for providing the best energy transfer rate according to technical specifications.

The same system is ready for the two charging scenarios, static and on-board, and it is comprised of different mechanical subsystems to ensure the right integration on the vehicle and the best functionality. The mechanical subsystems are 1/ a pick-up mechanism allowing translations in the direction perpendicular to the vehicle movement in order to achieve the appropriate air-gap between the two coils, 2/ a black box housing interconnecting all internal devices (drivers, limit switch, electromagnetic blocks, motors, etc.), while also allowing the connection of those devices to the EV, 3/ a guidance system comprising a slider and guiding arms, so as to ensure a good positioning while the secondary coil is moving upwards, 4/ a rolling system, a subsystem of 4 wheels close to the secondary coil in order to ensure the air gap defined in the specifications, 5/ a damping system absorbsing the roughness of the road, and minimizes the rolling noise, and 6/ a locking system locking the platform containing the secondary coil (integrated in the lower part of the secondary module) in the black-box housing.

The black box housing contains and interconnects all internal electrical/electronic subsystems including motors for vertical movement, coupled to the shaft with a gear and encoders, drivers that control the motors, limit switch that controls the end of stroke previous to lock the system, ultrasonic sensor that detects the ground during the downward movement, and electronic control unit that controls the motion of the black box, the communication with the EV and functions to command digital and analogue inputs and outputs.

The whole system is assembled and fixed at the rear end of vehicle chassis and works as a carrier of the secondary coil. It also contains other components such as the AC/DC module. The final system was tested before demonstration activities in order to ensure the compliance with the requirements and to avoid any kind of functional problem during operation in a real urban context by performing matching tests, static tests, dynamic tests, durability tests, field tests and EMC tests.

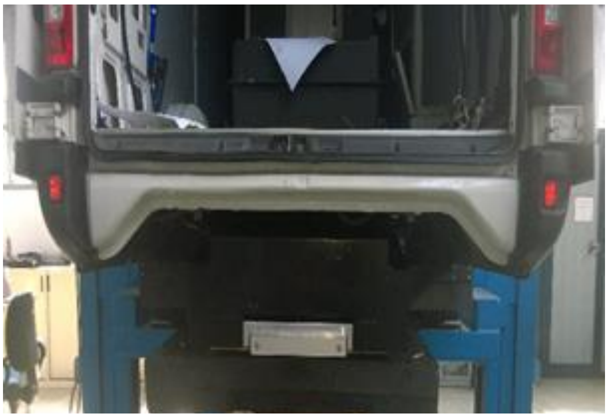

Figure 7 – Installation of the black box on the vehicle's chassis

6. Battery test bench

In an effort to anticipate potential problems on the interaction between the charging device and the battery pack, a battery test bench has been designed and realised. It includes the essential components required to emulate the behaviour of the vehicle during charging, but without the need to deploy the demonstrator vehicle. The HV battery pack and all the ancillary components installed in the battery test bench are identical to the ones that would have been installed on the demonstrator vehicle; obviously the software installed for the management of the charging process (e.g. contactors, actuators) can be a simplified release conceived to start debugging the establishment of the energy flow from primary to secondary and thus to the battery, the consolidation of awareness on issues related to the intervention of battery protections, on their effect on the charging device, and development of adequate countermeasures, the setting and calibration of the Wi-Fi communication between twin modules on vehicle and charging station sides, the calibration of the Vehicle Management System software for the parts related to the charging process management (except for the positioning mechanism's management and command that were not available at the time of the testing), and finally address possible electric and electromagnetic compatibility problems at an early stage of the design process without affecting the vehicle and reducing the time possibly required for recovery actions.

The aforementioned features allowed the designers of the IPTM system to perform a design review of the complete system tailored on the specific battery pack hosted in the demonstrator vehicle, achieving for instance lightweighting of the secondary coil and improved communication setup. In principle the battery test bench is capable of hosting also the complete secondary coil case like in the demonstrator vehicle (by replicating the chassis mounting), so this test bench could also be used to test the positioning mechanism and ultimately the dynamic charging.

Figure 8 & 9 – Battery test bench and secondary IPTM test bench

7. Vehicle integration know how

The different processes that led to the integration of the charging device in the vehicle permitted to acquire solid know-how concerning all the aspects that need to be assessed and addressed while dealing with the integration of dynamic wireless charging.

The integration involves both intuitive and less obvious aspects: the mechanical integration plays a significant role and has to be addressed carefully from the early stages of the design. However, electrical integration is critical as well in order to harmonise the vehicle equipment with the new technologies required to deploy the dynamic wireless charging. Last but not least, the communication integration is a very important part of the task, because the communication in the vehicle requires harmonisation between the new devices and the existing communication layers and protocols typical of automotive applications. Wireless communication is probably the main challenge, because the requirements of dynamic charging are on the edge of state of the art on wireless communication from vehicle to infrastructure, with the added complexity of the vehicle moving and charging.

The aforementioned challenges contributed to increasing awareness about the dynamic wireless charging potential and challenges, and this know-how can be exploited for future projects in this field of application. The key topics that contributed to acquire or improve know-how at the end of the FastInCharge project are 1/ Understanding of the changes required by the wireless charging device and related services and requirements to the Electrical/electronic (E/E) architecture of EVs, 2/ Dynamic charging requirements related to the opportunity and need to control the airgap and how to deal with it from the vehicle point of view, 3/ Charging compatibility with the HV system: the compatibility of the charger with the HV system on the vehicle, and especially with the battery pack, is crucial when designing fast charging devices, because the battery limits can actually hinder fast charging. It is really important that the charger be compliant in terms of current/power limits (transient and continuous) with the battery pack, otherwise having a fast charger could be practically useless for the vehicle, and 4/ Communication harmonisation: wireless charging requires wireless communication between vehicle and infrastructure. As a result it is necessary to consider and program a device capable of transmitting information back and forth on Wi-Fi systems between the vehicle and the charging station in static and dynamic mode. The project highlighted the current weak points and possible technological choices that could help in improving the reliability of the charging device. Similarly, knowledge about the integration needs on the existing automotive communication layer, that is based on CAN protocol, are important for the correct deployment of the technology.

8. Grid impact analysis

Due to the high amount of power required for the operation of fast inductive chargers it is important for the distribution system operators to be aware of the grid impact of static and dynamic fast inductive charging technology. In this respect, a grid impact analysis has been performed to evaluate the following aspects:

8.1 Impact of static and dynamic inductive charging on the distribution grid.

A software tool that estimates the energy requirements of static inductive charging, as well as a tool that identifies the maximum number of on-route chargers that can be installed in a distribution network without violating grid operational constraints have been developed. Regarding the input parameters of the demand estimation tool for static inductive charging, the probability of the occurrence of a charging event during a specific hour in the day and the probability for the duration of each charging event have been considered:

Home charging of electric vehicles has also been taken into account, considering both stochastic (arrival time at home, daily travel distance, number of vehicles charging at each power level) and deterministic (total number of EVs, type of electric vehicle, battery consumption) EV fleet parameters. The input parameters considered in the tool identifying the maximum number of dynamic inductive stations are the need for fast inductive charging and the traffic on the roads.

A grid impact analysis has been performed studying an urban Medium Voltage (20kV) distribution line. Various scenarios were simulated considering different percentages of EV users relying on static inductive chargers. The simulation results proved that the increased EV demand introduced by home charging during evening hours can be reduced if static inductive charging is considered. Static inductive chargers shift part of the evening EV charging demand during morning and middle day hours. The increased demand of static inductive chargers is not expected to provoke network operational issues. Local network issues might probably be raised if those static inductive chargers are concentrated in a small area where the network is already stressed. Moreover, the exploitation of static inductive chargers increases the potential daily operating distances of EV. In that case, the daily charging energy requirements are significantly increased resulting in increased grid equipment loading and network losses.

The maximum number of dynamic chargers that can be installed in a network without provoking any grid operational issue is highly dependent on the non-EV demand of the network as well as the number of static inductive chargers installed in the network. The simulation results showed that dynamic inductive charging introduces quite a considerable demand in the middle-day hours. The factors that limit the maximum number of dynamic stations that can be hosted in an urban grid are mainly the line loading or the transformer's available capacity. More specifically, the loading of specific lines within the grid is quite close to their thermal limit at the middle-day hours when most dynamic stations operate. Furthermore, quite a considerable increment is noticed in the daily active losses due to the increased energy demand of dynamic stations. On the contrary, the voltage maximum and minimum values, as well as the voltage deviation in the network's buses are well within the allowed limits.

8.2 Sensitivity analysis concerning the power transfer rate

A sensitivity analysis has also been performed in order to observe the impact of the power transfer rate when studying the impact of inductive charging on the grid. Different scenarios have been studied, considering different cases for the output power of the stations. It has been determined that when considering a charging power reduction of 20.9% then the number of static inductive chargers required to serve the same number of charging sessions is increased by 15.8%. As a result, a lower power transfer rate allows for a greater number of dynamic inductive chargers to be installed in the grid.

8.3 Inductive Charging and Renewable Energy Sources

The grid impact of inductive charging has also been evaluated, considering a near future scenario where a load increment (of either 5% or 10%) is noticed in the grid demand, while also taking into account different Renewable Energy Sources (RES) penetration scenarios (Photovoltaics (PV) with installed capacity of 10 or 20MW). It has been determined that although a load increment significantly reduces the number of inductive stations that can be installed in the distribution network, the installation of PVs allows more inductive charging stations to be installed considering the existing charging infrastructures and without implementing any EV management. More specifically, in case of a 5% load increment, the number of dynamic stations that can be installed in the network is reduced by 21%. This reduction can be limited to 7% in case local RES production is considered. Additionally, part of the charging demand of the stations is served by local PV production, leading to a decrement in the loading of the lines and the transformers, as well as a decrement in the network's active losses.

8.4 Grid Impact Analysis with the deployment of an efficient energy management system

The impact of inductive charging on the grid has also been evaluated considering the development of an efficient management system that can offer network support services. More specifically, it has been determined that the reduction of the charging rate in all stations (both static and dynamic) can release the network from a high consumption under a mass inductive charging deployment scenario.

The simulation tools that were developed can enable system operators to estimate the grid impact of EV charging considering conductive and inductive charging, and evaluate the current network capacity under different EV deployment scenarios. The outcome of these tools can be exploited for defining the charging station placement strategy that should be adopted as well as the potential grid investments necessary to support mass inductive chargers penetration. Moreover, the developed tools enable the better understanding of the grid impact of conductive and inductive charging, and provide interesting outcomes which can be used for further research activities, such as the development of innovative EV coordination mechanisms

9. Energy Management System

As the number of installed inductive chargers in the grid increases, the load profile of the network will be significantly modified, due to the high charging power served from this type of chargers. The additional charging demand may provoke grid issues such as voltage excursions, network overloading etc. Consequently, an Energy Management System is necessary in order to mitigate potential disturbances in the normal operation of the grid. The energy management system that was developed within the framework of the project enables the coordination of the charging network and offers several services to EV users. The proposed energy management system considers both the EV drivers' needs as well as the constraints that are set by the capacity of the existing grid infrastructure.

The energy management system fulfils the following objectives:

- Monitoring the operation of the charging stations: The energy management system allows the operator of the charging stations to monitor their consumption in real-time not only for billing purposes, but also to identify the demand flexibility that can be offered to support network operation.
- Enable the remote control of the maximum charging rate of the stations under emergency network operational conditions: In case that the network operation is close to its capacity limits (equipment overloading) due to the increased demand of the fast inductive charging stations, the energy management system enables the remote control of the maximum charging rate of the stations located at the specific part of the grid where the operational issue lies.
- User awareness of the location, the availability and the electricity cost of the fast inductive charging stations: The energy management system makes EV drivers aware of the locations of the existing fast inductive charging infrastructures in order to be able to decide the most convenient place for charging their EV in respect to their trip destination. Moreover, the energy management system informs EV drivers about the availability of the charging

stations. Finally, a pricing policy (energy consumption based or parking time-based) can be adopted in order to encourage charging during off-peak hours.
• Offer booking services to EV owners: enabling them to book the most suitable charging station at the most convenient time, considering their trip destination as well as the electricity energy prices: The energy management system allows EV drivers to book the future use of a fast inductive charging station which is the most convenient one, taking into account their travel plan, the energy mobility needs and the electricity prices.

The energy management system comprises three components which are 1/ the user awareness module, 2/ the monitoring module, and 3/ the decision module

When an EV owner needs to charge its EV battery, he/she will drive to the nearest available charging post. However, the closest fast inductive charger might be occupied and, consequently, the EV owner will have to find the next closest charging point (CP). For this reason, the user awareness module makes EV owners aware of the available CP as well as the estimated time when that busy CP will become available again. Therefore, based on their charging needs, their travel direction as well as the location of available charging stations, EV drivers can reschedule their driving route to the desired destination in order to reach the most convenient and available charging station. The interaction between the EV user and the management system is realised based on the Rest-based web services technology and can fit to any Android-based device (smartphone and/or tablet).

The monitoring module is responsible for the interaction between the charging station and the energy management system. It is responsible for communicating with the metering infrastructure of the charging station and gathering the data concerning the energy consumption. Moreover, the monitoring module is responsible for remotely controlling the maximum allowable charging rate of all the charging stations. The actual charging rate is defined by the battery management system of the electric vehicle which cannot be higher than the one defined by the energy management system. This interaction is realised in respect to the OCPP 1.5 protocol.

The decision module is responsible for purchasing energy from the wholesale market and for supplying the charging demand of EV drivers. EV owners will be charged for the energy price at constant rates in order to prevent their exposure to high market energy prices during peak hours. Different pricing policies may be adopted, either simple ones (i.e. multi-tariff) or advanced (dynamic pricing). Irrespectively of the adopted pricing mechanism, the energy price level is an indirect factor that affects the EV owner’s charging time decision. Furthermore, the decision module is responsible for processing any charging or booking request of EV owners. Finally, the decision module offers demand response services to the market operator. In case of network operational issues (voltage excursions or network equipment overloading), the decision module can support the problematic grid area by reducing the charging rate of the charging stations located at that area.

The interoperability of the developed energy management system concerning its interaction with different vendor’s charging infrastructure was assessed based on a three-layer testing procedure, starting by the implementation of OCPP protocol in the laboratory environment with two computers simulating the behaviour of the charging station and the energy management system, then by the implementation of the OCPP protocol between the energy management system and the charging station developed for the scope of the project, to finish by the implementation of the OCPP between the energy management system and a commercial home, conductive, charging station, which is compatible with this protocol. Interoperability purposes imply such an implementation.

The evaluation process was successfully completed proving that the developed management system does not pose any limitation to its usage in combination with commercial (conductive and/or inductive) charging infrastructures. The energy management system can benefit to both EV Supply Equipment Operators (EVSEO)/Suppliers using it as a complete management platform offering various capabilities such as monitoring, EV Supply Equipment (EVSE) remote control, billing, booking services etc, or to Distribution System Operator (DSO), benefiting from the exploitation of the demand response services offered by the EMS, preventing or postponing premature and costly grid investments due to the additional EV charging demand.

Potential impact and main dissemination activities and exploitation results

1. Potential impact

Technical potential impacts

The impacts on the grid

The FastInCharge project is a leading research project concerning fast charging without contact, using induction technology. In consequence, a lot of technical progresses have been made since the beginning of the project compared to the previous state of the art. Nevertheless, as the technology developed is new and is expected to skyrocket in the next years, studies have been made to evaluate the impact of this technology on the distribution grid.

In the calculations that have been made to understand the potential technical impact on the electric grid, input parameters that were put in the simulation to estimate the inductive charging energy requirements were evaluated to fit in the best possible way the mobility patterns of Douai city. More specifically, the arrival time of EV users at home at the end of the day as well as the average daily travel distance of EVs have been taken into account in order to define the energy requirements of home charging. Furthermore, the energy requirements of dynamic inductive charging have been evaluated taking into account data concerning the traffic on the roads of Douai.

Moreover, the demonstration results indicated a reduction at the output power of the stations due to EV battery operational constraints. Taking into account the reduction in the power transfer rate, the charging duration of a static inductive charging event has been redefined. In order to better observe whether the power transfer rate alters the results concerning the grid impact, a steady state analysis has been performed, considering an urban Medium Voltage (20kV) distribution line in the area of Katerini, Greece. The simulation results showed that a lower output power requires more static stations in order to cover the static inductive charging demand of a specific number of charging events. As far as dynamic inductive charging is concerned, it has been determined that the lower output power indicated by the demonstration results allows more dynamic stations to be installed in the grid.

Furthermore, the grid impact of inductive charging has been evaluated considering a near future scenario where a load increment is noticed in the grid demand. A number of different scenarios with a varying load increment and a varying installed PV capacity have been considered. Inductive chargers introduce a significant demand during the middle day hours, which is synchronized with the peak in the grid demand. PV production, however, is capable of covering a significant amount of this demand, introducing quite a considerable decrease in the grid’s load curve during the morning and middle day hours. In the event of a load increment, the maximum allowable number of dynamic chargers significantly decreases. However, the installation of PVs in the distribution network is capable of increasing the number of dynamic stations that can be installed in the grid. Additionally, PV production considerably decreases the daily active losses within the distribution network even when considering the energy requirements of an increased number of dynamic stations.

Understanding of range anxiety reduction in EVs

During the demonstration activity the actual power transfer levels for the IPTM have been validated during the testing campaign, demonstrating the potential of the solution to withstand dynamic charging at around 30 kW at very low speed and for very short distances. This result is particularly important when looking at the potential deployment of this technology, with the ultimate goal of realising dynamic charging lanes, with speeds higher than what has been tested in the demonstration. When such a technology will be implemented the electric vehicles could undergo a radical breakthrough, since charge-while-driving could reduce the amount of energy to store in the battery pack by design, implying consistent weight and cost reduction, since this component is one of the main drivers for both parameters. At the same time, the driving range could increase dramatically with respect to the 100-150 km that nowadays the majority of EV models in the market proposes. All these changes could lead to a change of mentality, by reducing the so-called range anxiety that is one of the main hindrances to the diffusion of the e-mobility paradigm. The project analysed the dynamic charging potential for the technology under demonstration. Even with relatively small fractions of the road covered by charging tiles, the battery pack balance could be made positive, which means not only powering directly the vehicle from the infrastructure, but also recharging the battery at the same time, increasing further the range. Hypothetically, it can make the need for a battery pack worthless on EVs, which could simply run at zero-balance receiving all the energy the vehicle needs instantaneously from the grid under the constraint of travelling only on the energised lane.

The next generation

Other potential impacts are the direct consequences on the future products that can be developed using the same technology or similar ones and more specifically the integration of electro-mechanical devices in electric vehicles. Indeed, thanks to this successful project and the knowledge that have been acquired, the companies of the consortium are thinking of the next generation of products that the technology developed can enable.

Sociological potential impact

It would be a mistake to focus only on the technological potential impacts because when it concerns innovation, the sociological potential impact can be decisive for the success or the failure of the spoken innovation. This is particularly true when the innovation leads to an important change of behaviour as it can be the case here. This is the reason why a social impact study has been led in the FastInCharge project.

The solution can have a positive impact on transport systems in different city environments facilitating and simplifying the use of battery-charging infrastructure for a wide range of users. Wider society-wide impacts are 1/ Reducing the concentration of unhealthy emissions from transport: the city supports a proactive approach to curb climate change, 2/ Reducing noise levels in the immediate vicinity of the road infrastructure and also in the broader area, 3/ Stimulating new industries with the potential for creating new jobs and strengthening the economy, 4/ Preparing the public administration to start using electric mobility to a greater extent immediately after it becomes cheaper, 5/ Improving opportunities for inhabitants who are interested to contribute to cut their emissions in the context of climate change by their own lifestyle, 6/ Creating a more attractive place to live in and total capital advanced image support (important for attracting top experts and investments), and 7/ Allowing a greater democratisation of the use of electric vehicles and charging infrastructure.

Contactless induction charging can dramatically change the "usability" and appeal of electric vehicles for consumers and enhance user comfort. Although talking about the widespread use of contactless charging is quite early, there are commercially available solutions that are useful for particular brands of electric cars.

A sociological impact that also exists is the increase of expertise that the consortium experienced thanks to this project, as well as subcontractors or other companies that have been in contact with the project through the dissemination of the results and the communication of the project. This increase of the European expertise is a social impact that exists in every research project that makes improvement in its field, and that also results in a competitive advantage.

Potential economic impact

An important aspect of a new technology is the economic viability. Indeed, as this solution was developed thanks to European funds, it was necessary for the FastInCharge project to show that the solution invented is economically possible. This is the reason why a study on the economic impact of the technology developed in the FastInCharge project has been done.

The discounted cash flow analysis that have been done in the project can be very close to an intrinsic stock value and is able to give a good idea of the value of a company or project. The main difficulties of this study came from the absence of any previous financial information on the concept.

Indeed, being funded by the European Commission, the first idea was not to make profit during the project but to develop an innovative technology and help the involved partners to develop it without huge private investment. Thus to determine future cash flow, many assumptions were done in accordance to the market tendency and the results of companies in the same field (Tesla and Qualcomm). Tesla is selling EVs and installing static charging infrastructures in the USA and Qualcomm is developing and testing inductive charging for EVs, both companies have similar R&D activities than those developed by the project.

However these assumptions can be flossed and the results are to be taken into account with high precaution. The results shown by this analysis indicate that the concept is indeed viable under certain conditions and time frames. The terminal value reaches more than 3.5 million euros, and net present value reaches break-even point under 10 years. For such a large project requiring large infrastructure investments, these figures are pretty encouraging. Higher levels of charging infrastructure significantly increase the take-up of electric vehicles and hence increase the viability of the market.

Other key factors affecting both take-up and viability include the vehicle cost and rate at which it converges with ICE vehicles (largely driven by battery costs), fuel prices (particularly higher oil prices), vehicle range and the existence of local supply constraints. Vehicle costs and vehicle range are expected to converge over time as technology improves and production increases, therefore the removal of supply constraints and the provision of charging infrastructure are the key areas that warrant further attention if the take-up of electric vehicles are to be encouraged.

A sensitivity analysis has also been performed on the cost benefit scenario performed previously. However, general strategy of the concept development would have to be taken into account to deliver a full understanding of the concept potential and risks. For instance, what if the main market was only the public transportation market? Change in the forecasted costs and revenues have impact on the concept viability, however none of them are an immediate threat, the main impact is to decrease the net present value and terminal value, but the switching values are almost the same. The sensitivity analysis emphasises the absence of noticeable changes in the break-even point, with a variation from 12 to 14 years only. The concept seems still viable under different scenarios and its sensitivity is not too important to have any specific recommendations on potential risks.

The main conclusion is that such a technology is economically viable and is rather little sensitive to external changes under certain circumstances.

2. Main dissemination activities

The dissemination activities of the FastInCharge project aimed to diffuse the knowledge acquired through the research work towards the scientific community, automotive and transport industrials and to communicate on the results of the project towards municipalities, transport associations, national agencies and European institutions, citizens and general public. This wide audience targeted by the consortium implied to develop different levels of dissemination in order to reach effectively each target public.

The website

The first and biggest tool that reaches a wide public is the website (http://www.fastincharge.eu). All the results are available on a dedicated tab of the website through the public deliverables and a page on the Open Day. Moreover, both webinars that have been done during the project are available to watch on video in the communication tab of the website.

The Open Day

The biggest event organised during the project was the Open Day in Douai on June17th, 2015, where prototypes were ready to be demonstrated for the public and professionals. Twelve posters were created for the citizens of Douai and surroundings. A lot of key notions were addressed with simple words in French and in English in order to reach a wide audience. The subjects of the posters were the followings: Electric vehicle: Myths vs Facts, The city of the future, The Energy Management System, History of the Electric Vehicle, Basics on the Electric Vehicle, The cost issue, Electric vehicles and charging stations, FastInCharge project, induction technology.

A questionnaire was also given and people that get all the answers right could drive an electric car. During the Open Day, a lot of questions from citizens to partners were initiated by the posters. A “drawing contest” was also organised for kids and the theme was “the vehicle of the future”.

At the beginning of the day, the Mayor of Douai, Frederic Chéreau, explained to the citizens that were here for the presentation the interest of the project for the city. Then, the CEO of DBT, Hervé Borgoltz, explained to the citizens the principle of the project, followed by the project coordinator for more precision.
DBT and its 8 European partners were proud to present the first induction fast charger. The first demonstration was on the dynamic site where Douai citizens and professionals were able to see the FastinCharge vehicle drove above captors installed directly on the road at a speed of approximatively 15km/h, Avenue de Strasbourg in Douai, charging by induction during a few seconds until the stop sign that is on the end of that street. The FastinCharge team also did a static demonstration in another part of the city where the charging station was installed even though less people participated to this second demonstration, because it was simply less impressive than the dynamic one as the principle is the same except the vehicle is not moving. This Open Day was a success for the partners and for the project.

FastinCharge team

The webinars

The webinars were also another strong dissemination activity. Indeed, two webinars were organised during the project and videos were taken so that people that missed the event but wish to learn about what had been said can still watch it on the website of the project. The second webinar was organised at the end of the project so that the results can be fully presented.

Articles

To target the scientist community, a very important audience in this project as it is fundamental research, several articles and scientific journals were published. 9 peer reviewed articles were published in 8 different scientific journals during the time of the project which is a very good amount and helped a lot for making the project known among the scientific community.

Events

Smaller events were organised in the six different countries where the partners are (France, Spain, Italy, Greece, Bulgaria and Slovakia) and results were presented through presentations in little Open Days or conferences or other specific occasions. This mean of dissemination is efficient because it mainly reaches people personally concerned and interested by the results of the project.

3. Project final results, their potential impact and use

The project outcomes will enhance the attractiveness of electric mobility for vehicle owners because it allows a more convenient interaction with the charging infrastructure; the time of charge is greatly reduced and the range of the vehicles is very much increased. Moreover it helps reducing the cost of ownership by reducing the size of onboard batteries, which corresponds currently to an important fraction of the price of the car.

The main sector of application targeted by FastInCharge is electric vehicle battery charging. It is expected that in the next years, the number of functional charging stations will increase greatly, especially when cities start implementing functional on-route charging infrastructures. In order to avoid the problems of misalignments, the solution proposed in the FIC project will be recommended.

Since FastInCharge is a modular infrastructure solution, not only the market of the technology is targeted, but also the market of the integration and adaptation of the system to different EV brands. A specific study has even been made at the end of the project to evaluate an easy adaptation of the project inductive charging solution to a passenger car with preliminary promising results.

FastInCharge will stimulate the innovation of the electric vehicle industry in Europe by having explored new technological solutions to ensure the charge of EVs. This is expected to result in the creation and development of an electric vehicle charging value chain (from the design of the infrastructure, product development, infrastructure integration until the integration of the secondary device in the EV). By integrating all the chain in the project, the market uptake of the charging infrastructure will be facilitated as the secondary device will answer the specific needs and constraints of the various EV brands.

FastInCharge project will facilitate the adoption of a shared and strategic vision on key enabling technologies such as electric vehicle charging and encourage key actors, i.e. the European institutions, EU countries, EOMs, businesses and other stakeholders, to work in partnership in order to ensure the successful deployment of innovative solutions

Finally, FastInCharge will bring its contribution to the achievement of the environmental and economic targets of the European policy initiatives. The potential implementation of the innovative results will, on the long term, enhance the electric vehicle industry in the European community.

Public website address

www.fastincharge.eu