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ESPRIT project: an innovative electric car sharing solution

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Abstract

ESPRIT project is an important research project financed by Europe for 8.9 M€ in the framework of the program H2020 and coordinated by CEA (Commissariat à l'énergie atomique et aux énergies alternatives). The goal of ESPRIT project is to decrease the usage of individual cars in urban area and to complete the usage of public transport. It is ESPRIT deals with the development of some small electric cars which can be mechanically coupled to create road trains. This vehicles can be used within a carsharing system in city center and peri-urban area. These vehicles will allow for user to complete a trip done with public transport and perform the first or the last kilometer with a non-pollutant system. The aptitude to be coupled in road train allows the redistribution to secure the availability of vehicles in stations. That permits to propose a high reliability system with a limited investment cost. This paper shows the work done during the 3 years of the project. In 2016 a first paper [6] about this project was presented in PCIM: "Comparison between standard and innovative solutions to exchange energy between high energy storage systems". This first paper was dedicated to a sub-system inside the vehicle. In this second paper we are more focusing on the final results of the project.

1. ESPRIT project

Goal of project is to solve with technical innovation the current main issues of existing carsharing system.

11. Investment cost

First of issues is the investment cost. A classic carsharing system need to invest in stations with almost one point of charge for each vehicles. ESPRIT concept is to store vehicles in station in road train configuration (Figure 2). In this configuration, vehicles are electrically coupled. Thus an unique charging station allows to charge the complete road train (8 vehicles maximum for the moment). That decreases significantly the cost.

Space of station in the street is reduced due to the road train configuration. The place needed by 8 ESPRIT vehicles in a road train is equavalent to the one needed by 3-4 conventional cars parked one behind the other. That is the second raison which explains a lower investment cost that conventional carsharing system.

12. Distribution cost

Like all carsharing systems (cars or bikes) where the vehicle is taken in a station and restituted in another one (called 'one way' systems), there are always empty and full stations depending of the hour of the day.

Often, people do the same trip at the same hour to go to city center or to come back at home at the end of the day, thus emptying some areas and saturating others. Re-Distribution of cars to rebalance the distribution of vehicles is of course more difficult to handle than with shared bikes. Two persons are needed to redistribute one car. The use of big trucks in city center to redistribute vehicles is too difficult and sometimes forbidden.

The road train configuration of ESPRIT vehicles allows (Figure 1) to drive up to 8 vehicles at same time. One operator can distribute 8 cars by 8 cars, enabling a productive and effective rebalancing of the fleet.

13. Reliability

The majority of ‘one way’ carsharing systems does not work at 100% of capability. Vehicles are not so used in comparison with the maximum possibility. This phenomena is mainly due to the bad confident in the system for the user.

If somebody is late to an important meeting for job because of its unability to find a vehicle (the station near to home was empty), the next day, he will take another transport service. That’s why the distribution is absolutely essential in a ‘one way’ carsharing system, to build customer loyalty.

In station, ESPRIT work like FIFO system. The first vehicle will be used in first and the vehicle is restitute by the back. Operator can choose the number of vehicles he want to redistribute from one station in order to complete another station.

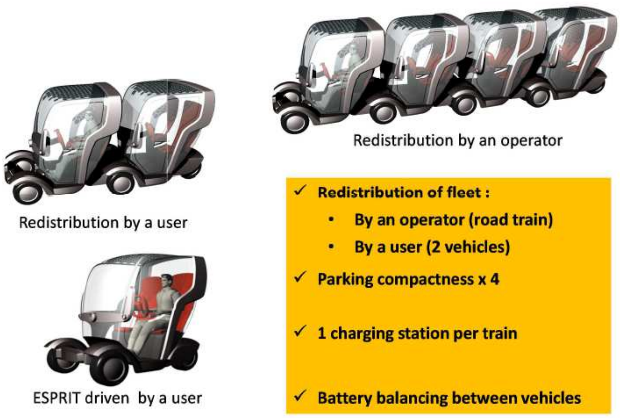

Fig. 1: ESPRIT concept

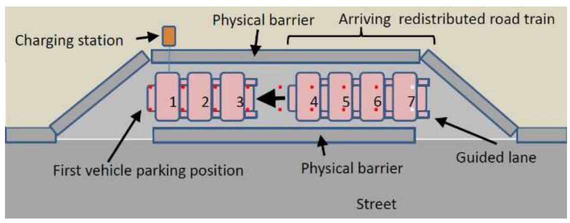

Fig. 2: ESPRIT station

2. Technical innovations

Currently, the maximum number of vehicles in an ESPRIT road train during a distribution is limited to 8. This train is particular because the first vehicle can’t tow alone the 8 vehicles. Firstly, because it has not enough power and secondly because, due to the homogenous repartition of mass oscillation phenomenon may appear. The phenomenon is greatly amplified if there are several trailers.

To solve these issues, all vehicles participate to the propulsion of the train. Each vehicle power supplies their own electrical motors, so there is no vehicle towed. To do this, a communication between vehicles is necessary. First vehicle is the master and the followers become slaves and execute orders given by first vehicle. It calculates in real time the oscillations of the road train with data provided from sensors placed in each vehicle. Algorithms determine the compensation needs and send orders to each vehicle independently.

To facilitate the oscillation compensation, ESPRIT vehicle is equipped with two motors. One on the back left and one other on the back right. With an intelligent command of torque on each motor, the oscillation can be controlled in real time. Another action can be apply on the front wheels. The drive of steering system (2 or 3 degrees) may also have a big impact on the oscillation compensation. A hydraulic damper is also used . The last possible action is to drive brakes by wires. An independent action on each brake of each wheel of the road train can also help to compensate the oscillation.

The detail of algorithms used to do this compensation is already exposed and is the subject of other publication [7].

From hardware point of view, the necessity to control each steering system, each motor and each brake of each vehicle means to be equipped with electrical components driven by a communication bus. For motors, and steering, that is not a big problem to find electronical components with communication bus. But for brakes, it was more complicated. A conventional brake system is piloted mechanically with the pedal. A hydraulic assistance is applied and distributed on each wheel (ABS system). For ESPRIT project, a specific brake by wire was designed by Continental. This brake can receive orders from CAN bus (controller area network) and manages independently the pressure in the brake of the four wheels.

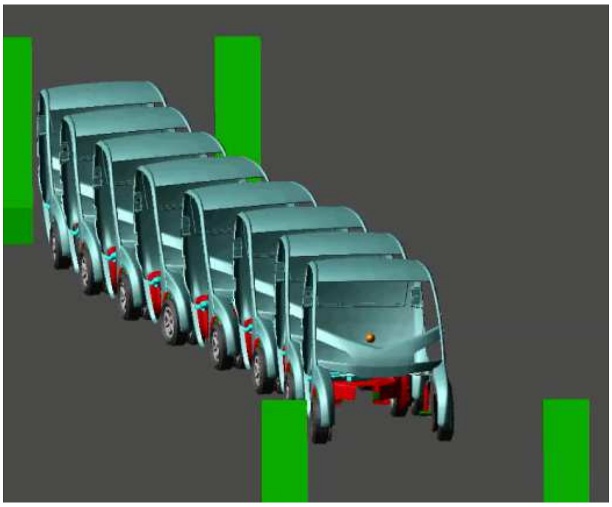

Fig. 3: Simulations of roadtrain stability

3. Electrical architecture and power electronics

31. Electrical architecture

The electrical architecture (see Figures 4 and 5) at the vehicle level is a standard one, in which we can find:

- Battery system, inverter and motor for the electric powertrain
- Isolated DC/DC converter to the supply the 12V auxiliary network
- And a 3kW embedded charger to charge the battery

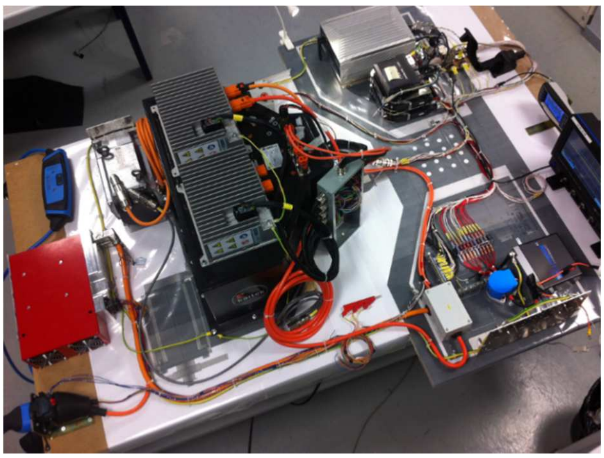

Fig. 4: Mockup on table

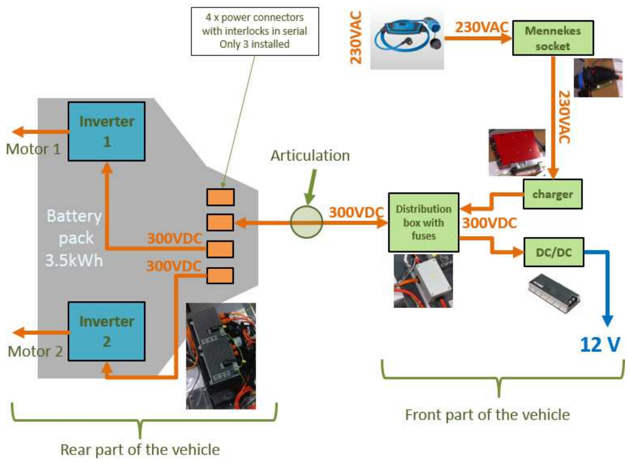

Fig. 5: - Synoptic of electrical architecture

The electrical architecture at the road train level is more complicated because completely new functions must be implemented to ensure firstly the transfer of energy between vehicles (to charge batteries or to balance energy between batteries) and secondly the safety of the user.

Concerning the transfer of energy between vehicles, different solutions have been compared [6], but at the end the preferred solution will be an AC bus associated with bi-directional chargers and contactors (see Figure 6)

Concerning the safety, the most important is to ensure and monitor the ground continuity between vehicles.

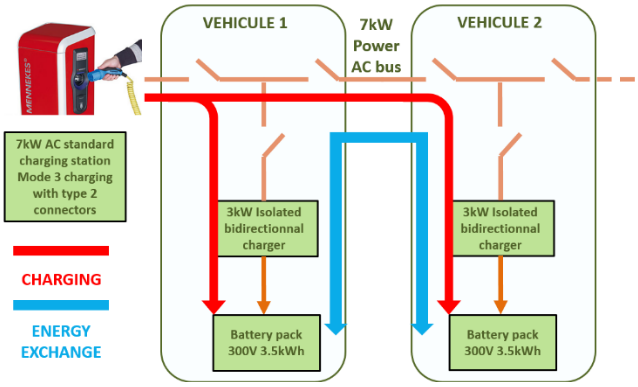

Fig. 6: Energy transfer in the road train

There are different possibilities to exchange and transfer energy between vehicles (V2V) or from station to vehicles. For that it is possible to drive different embedded contactors and chargers located inside each vehicle. Vehicle number one is the master. It will be in charge of defining priorities, powers and thus the charging sequence.

The possible solutions (see fig.6) are:

- Solution 1: Charge only one vehicle (red flow). Maximum charging power is 3kW
- Solution 2: Charge **N** vehicles (red flows). Maximum charging power per vehicle is 7kW/**N**
- Solution 3 : Exchange energy between vehicles (blue flow). Maximum power is 3kW

32. Power electronics and motors

At the beginning of the project, the design of the electric powertrain was one of the most important task. The main specifications can be summarized in the following items

For the battery:

- Minimum range of the single vehicle when loaded (between 600 and 800 kg) : 35 km
- Life time objective without maintenance: 10 years
- Small and specific volume due to the vehicle configuration
- High voltage (300VDC) battery system to allow fast charge
- Crash safety and waterproof

For the inverter, motor and gear:

- Loaded, the vehicle should reach the maximum speed of 65 km/h
- Fully loaded the vehicle or the road train should be able to start in a slope of 13%
- The vehicle or the road train should be able to be driven at 15 km/h in a slope of 20% during 2 minutes
- Fully loaded the vehicle or the roadtrain should be able to reach a speed of 45km/h in less than 10

The battery pack

Finally, the battery pack designed to fulfill the vehicle specifications was a Lithium Iron Phosphate battery system composed of an assembly of twelve modules in serial. Each module is also an assembly of 40 (8 serial 5 parallel) small cylindrical cells, with individual capacity of 2.3Ah. That gives a 300V 3.5kWh battery pack (see fig. 7 and 8) allowing a maximum charging current of 35 A

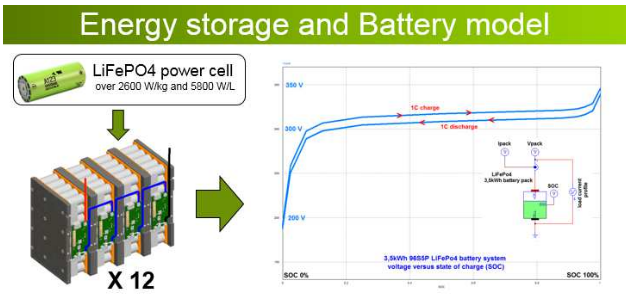

Fig. 7: Battery pack design

Fig. 8: Battery pack manufacturing

Inverter motor and gear

The choice of the best configuration for motors and inverters was performed thanks different tests at sub-systems level (see fig. 9 and 10). The objective was to measure power and thermal behaviors of different motors and inverters. Then thermal and losses models were created in order to evaluate maximum temperatures in function of power profiles, ambient temperature and also weight of the vehicle. With maximum temperatures limited around 115°C in the inverter and 150°C in the motor, we can optimize motor choice and gear ratio.

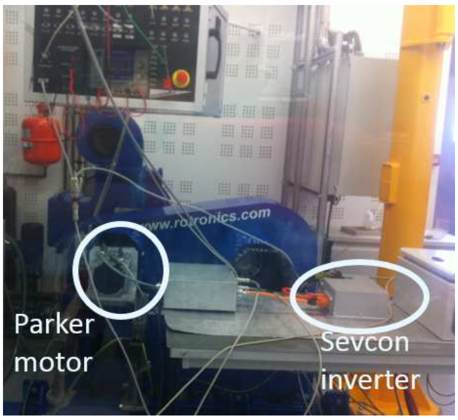

Fig. 9: Motor test bench

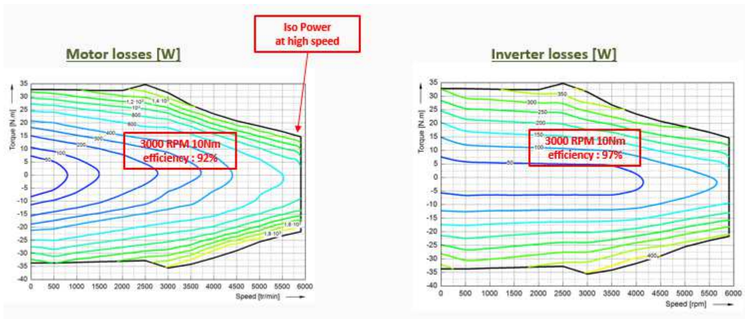

Fig. 10: Losses evaluation in function of torque and speed

4. Project chronology – prototypes

Regarding the number of mechanical and electrical sub-systems to build this vehicle, the development was organized in several steps.

The **first** prototype contained the strict necessary elements to move the vehicle: battery pack, motors, inverters, charger, DC/DC converter, intelligent unit who manage the security and start auxiliaries, intelligent unit which manage motors, screen, “Drive Neutral Rear” buttons and a datalogger to monitor the communication bus. This first vehicle is constituted with a steel chassis (easy to realise) and had the objective to check and validate the concept and propulsion chain. This vehicle was sent in Germany in order to develop, check and validate the special brakes. This first vehicle was very important for project because it was the basis of the other vehicles, in which we made mainly adaptation and improvements.

Fig. 11: First prototype

A **second** prototype was done on the base of the first one with adaptations of mechanical parts. The assisted direction piloted by the intelligent unit which controls motors was added and tested. Then this vehicle was sent in Germany to include the automatic guiding system which helps the user to align the vehicle for coupling. Some mechanical modifications were done on central pivot.

Fig. 12: Prototypes 1 and 3 in road train

A **third** prototype allows to develop the coupling device. Tests of traction was done in road train with prototype number 1 (updated to be setting in road train). Communication inter vehicle was also coded and validated.

The **fourth** prototype (see Fig. 13) allows to do a technological gap because chassis becomes in aluminum to replace steel and win mass. A road train (see Fig. 14) was done with prototypes 1, 3 and 4. This road train does tests of road holding and brake on a racetrack.

Fig. 13: Prototype 4

Fig. 14: Prototype 4 in roadtrain with 1 and 3

Prototype number **five** allows the development of auto body and corrects some electrical and software bugs. Other equipments like lights, klaxon, and wiper are integrated and validated. For all of these equipment the communication between vehicles in road train is necessary. For

Fig. 15: Prototypes 4, 5 and 6 in road train [2]

example, only the first vehicle can powered the full light.

To finish, prototype number **six** was delivered in last June. It integrates all functionalities developed until now.

Prototypes 5 and 4 were updated to integrate all functionalities and allows to do a complete finish road train with 3 vehicles.

5. Demonstration

Since last august, several demonstrations were done in different European cities: Lyon, Glasgow and Hospitalet de Llobregat.

Many medias [1], [2], [3], [4], [5] cover these events (Euronews, BBC news, Le progrès, France 3, Lyon première, The Herald, La tribune, Intelligent transport ou encore Bref Eco, …)

6. References

[1] https://acteursdeleconomie.latribune.fr/innovation/2018-08-30/une-nouvelle-solution-d-autopartage-bientot-en-test-a-lyon-788867.html

[2] https://www.leprogres.fr/multimedia/2018/08/29/un-nouveau-systeme-d-autopartage-en-demonstration-a-la-confluence

[3] https://www.brefeco.com/actualite/innovation/autopartage-le-projet-europeen-esprit-la-conquete-de-lyon

[4] https://www.bbc.co.uk/news/uk-scotland-north-east-orkney-shetland-45508652

[5] https://www.intelligenttransport.com/transport-news/71674/a-new-stackable-electric-public-transport-system-commences-testing/

[6] Laurent Garnier, Daniel Chatroux, Sébastien Carcouet, Julien Dauchy : Comparison between standard and innovative solutions to exchange energy between high energy storage systems, PCIM 2016

[7] Eric Lucet, Alain Micaelli: Stabilization of a road-train of articulated vehicles", Robotics and Autonomous Systems