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An Electric Crossover Concept Car

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Summary

The paper presents the ELECTRON Concept Car, Battery Electric Vehicle developed within the *Automotive Engineering* Research Centre of the University of Pitesti in order to create a low cost green vehicle for promoting the electric mobility. This concept car was built on the compact crossover car DACIA SANDERO STEPWAY by implementing an electric equipment FWD (Front Wheel Drive) type. For reason of cost this electric drive includes an asynchronous electric motor type and a traction battery with LiFePO4 technology. This concept has three ways of charging: regenerative breaking, by conduction (cable) with home WALL BOX and by induction (wireless, in stationary mode) with an original device developed in the project. The induction charging system is developed by ICMET (National Institute for Research, Development and Testing in Electrical Engineering, Romania). The IPT (Inductive Power Transfer) is designed and built entirely in Romania.

Keywords: passenger car, BEV (battery electric vehicle), lithium battery, inductive charger, training

1 Introduction

The paper presents for the first time the details of the Dacia ELECTRON concept car (Figure 1). It is a compact electric vehicle developed within the *Automotive Engineering* Research Centre of the University of Pitesti in order to create an experimental green FWD crossover car.

This new concept is developed on the mechanic platform of the Dacia SANDERO STEPWAY II, the successful European crossover car made by the Automobile Dacia - Group Renault at their plant located near Pitesti city, Romania.

This study is an academic project and has no connection with the projects or future car models of Automobile Dacia-Group Renault.

The paper also presents the development and implementation of the wireless charger with a power at least 3 kW for Dacia ELECTRON, that serves both for current exploitation of this system but also for staff training for all university level in EV operation of such systems. There are described the choosing topology of the inductive resonant coupler, issues of standardization, efficiency and interoperability, building and operation of the medium frequency inverter with variable load to charge batteries, the experimental verification system both on the test bench fitted with the necessary electrical/electronic facilities and on the car in question.

Figure 1. Dacia ELECTRON Concept Car, battery electric vehicle

2 Project objectives

The project objectives enroll be the strategy "Romania must to be close to Europe 2020 targets" which are the following:

- Capitalizing on previous experience to achieve at today's standards a compact electric vehicle for "On the Car Training"- Electric Vehicle module, a training program in the electric vehicle domain within the *Automotive Engineering* Research Centre of the University of Pitesti
- All Level Staff Training for plug-in and wireless charging in Romanian high schools

3 Dacia ELECTRON Concept Architecture

The architecture of the electric propulsion system of the Dacia ELECTRON is presented in Figure 2. This propulsion system FWD is a mono-motor type and includes: the Traction Battery assembly (1) with two stacks located in the central and rear sides, the high voltage conductors (2), the Connexion Box (3), the Traction Inverter Module (4), the Electric Machine and the transmission composed by the Coupling (6), the Reducer mono-rapport (7), the Differential (8) and the Drive shafts (9).

The battery charges whenever the vehicle decelerates. When the driver lifts his foot from the accelerator pedal, the vehicle's kinetic energy is recovered by the electric machine (5) (in generator mode) and is converted into electric current. The current generated is stored in the traction battery (1).

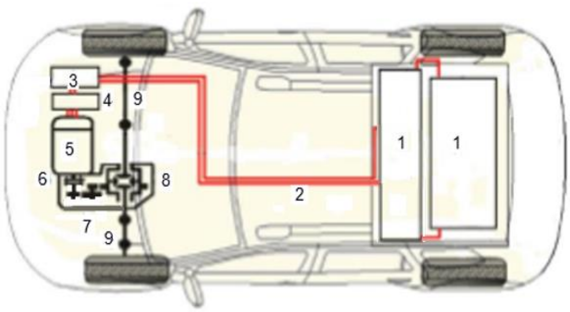

Figure 2: Architecture of the ELECTRON electric powertrain

4 Electric Powertrain System

The *AMBRA* (*Amber = Electron* in Greek language) electric powertrain system of the *ELECTRON* concept is built according to the current standards of the electric vehicle components (connectors, cables, fusible etc.).

This new system was designed based on the experience gained from the recently project *SEPIA 4WD* (*Systeme Electrique de Propulsion Integrale pour Automobile*) electric powertrain used by *Duster Z.E.RO* (Zero Emission ROmanian concept), built on the Dacia *DUSTER 4WD* [1].

For cost reasons the electrical components were taken from *ELECTRA* electric powertrain system (electric motor and transmission). They have been used in several different electric vehicles and hybrid vehicles concepts like*: GRAND SANDERO HYBRID E4WD* (building on the Dacia Logan MCV) [2], *GRAND HAMSTER HYBRID E4WD* (built on the Dacia DUSTER FWD) [3], [4].

The electric powertrain assembly is located in the front side of the vehicle, in transverse position (Figure 3).

Figure 3: Dacia ELECTRON Concept motor compartment

It includes: the Connection Box and the Charger, the Traction Inverter Module, the Electric Machine (the electric motor) and the Transmission FWD type. This component is mounted on the frame newly built, similar with the vehicles Renault ZE.

Figure 4 shows the general scheme of the electric powertrain assembly and the connection of these components with the traction battery, the embarked part of the dual recharging batteries system (by conduction and by induction) and the comfort system parts (AC compressor, heating unit with resistors PTC).

The electrical power circuit include: the Traction Battery assembly with the cells packs, the „Plug service” (1) wit Fusible integrated and the General Contactor (3) with “Precharge Resistor ”(4) ; the Connexion Box with commutator (5) for the charging mode type (conduction/induction), fusibles for AC compressor (6), Heating Unit PTC (7) and the Charger; the Traction Battery Charger; the Traction Inverter Module and the control motor; the Electric Motor; the Charging Socket; the Vehicle Receiver Unit with the Pick-up Rx Pad of the Inductive Power Transfer (ITP) with receiver coil Rx (8) and Rectifier (9); the comfort thermal components: AC Compressor and the Heating Unit with resistors PTC (Positive Temperature Coefficient).

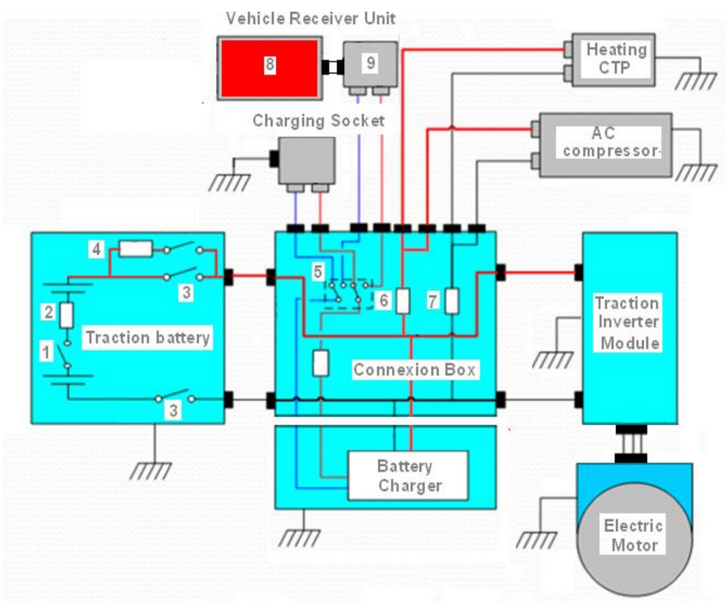

Figure 4: The electrical power circuit of the *AMBRA* electric propulsion system of the *ELECTRON* Concept

4.1 Connexion Box

This assembly is placed on the top of the power-train (Figure 5). It is realised using components already launched on the market for commercialized vehicles Renault ZE made by LEAR Company.

In the charging mode, the Connexion Box receives the energy from the charging socket or from the Inductive Power Transfer (IPT) - vehicle part and distributes it to the traction battery charger. The switching charging mode Conduction/Induction is made by the commutator 5 (Figure 4).

In the traction mode, the Connexion Box receives the energy from the traction battery and distributes it to the electric motor by the inverter.

On comand, the AC Compressor and the Heating Unit are fed by the Connexion Box.

Figure 5: The top level of the *AMBRA* powertrain (left) with the Connexion Box (top right) and the Traction Battery Charger (left) with the electronics from the Zivan NG3 Charger (down right)

4.2 Traction Battery Charger

The electronics of the on-board battery charger are mounted under the Connexion Box (Figure 5, low right). It is ZIVAN NG3 type, single phase, from Italy. This charger is an isolated, high frequency switch mode charger suitable for lithium battery pack. It is fully automatic and microprocessor controlled, with internal protection against overload, short circuit, incorrect connection and voltage transients.

The characteristics are: input – 240V 15A single phase AC, nominal pack voltage – 230V, charge rate - 8A, efficiency - 85-90%, operating temperature range: - 20°C to 50°C.

4.3 Inverter and control motor

The inverter assembly (Figure 6) made by MES SA company, Traction Inverter Module TIM 400 type, fluid cooling is a powerful electronic for electric machines in hybrid and electric vehicles versions. It is compact in size and weight, and it has a very high power density.

The inverter drives the electric machine both in motor and in generator mode.

Figure 6: The medium level of the *AMBRA* powertrain with the Traction Inverter Module TIM 400 type from MES SA

4.4 Electric Machine and Transmission

The ELECTRON concept is powered by an induction electric motor type 200-150W, liquid cooled, made by MES SA – Switzerland. The maximum continuous power is 18 kW (24.5 bhp) and 31 kW (42 bhp) at peak. It generates a maximum continuous torque of 90 Nm @ 2850 rpm and 160 Nm @ 1400 rpm at peak.

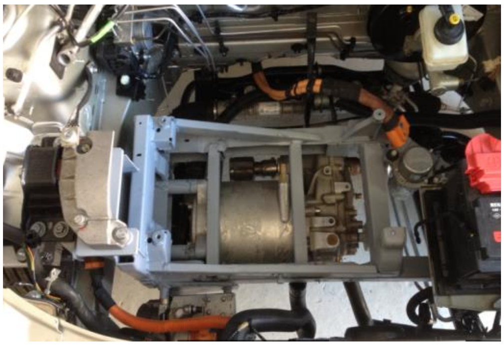

Figure 7: The low level of the *AMBRA* powertrain with the Electric Motor and Transmission Unit

Due to the favorable characteristics of the electric motor the transmission does not require clutch, gearbox or reverse gear. The mechanical transmission includes the reduction & differential gearbox unit and two new shafts adapted to the new vehicle front axle kinematics.

The Dacia ELECTRON concept can be driven similar to a vehicle with automatic transmission. The selector lever (Figure 8) has four positions. P: park; R: reverse; N: neutral; D: drive. The drive mode switch is given the command by a cable (for the forward, the neutral and the reverse mode) and the Parking Lock device. The display of the instrument panel (Figure 8) shows these modes.

Figure 8: The ELECTRON –Electric Vehicle cockpit

5 Traction Battery System

The Traction Battery System includes the Battery pack, the Battery Management System, the Plug Service device (1) and the General Contactor (3) presented in Figure 4 and the Battery Monitor System.

5.1 Traction Battery pack

Dacia ELECTRON traction battery, Lithium Iron Phosphate (LiFePO4) technology, contents 64 modules LYP 60 AHA from Winston, PR China, coupled in series.

This battery is divided in two stacks of 32 modules each; the first stack is located in a central position beneath the rear seats and the second one is located above the rear axle. This new architecture was chosen to boost the same load capacity as the internal combustion-engine version.

The characteristics of Dacia ELECTRON traction battery are: 230V maximum voltage, 12,3 kWh energy and 160 kg weight.

5.2 Battery Management System

The Battery Management System includes 64 Battery Management Cells and a Management Control Unit MCU-EV2, provided by EV Power Australia. The Battery Management Cell is an analogue cell module suitable for Winston LYP60AHA.

By connecting the signal output from the serial cell module and the master unit, we managed the protection against overcharge and over-discharge. The battery pack Master Unit monitors the signal of the cell modules and acts to prevent charging or discharging if the heartbeat signal is broken.

5.3 Battery Monitor System

The Battery Monitor System includes the battery monitor, a gauge, a 500A shunt resistor and a 10:1 pre-scaler. The battery monitor is an “e-xpert pro-hv “from TBS Electronics Holland. This e-xpert pro selectively displays the battery voltage, the charge and discharge current, the consumption, the remaining battery capacity and the time remaining. This instrument monitors also the 12V auxiliary battery of the car.

6 Traction Battery Charging

This concept car has tree ways of charging: regenerative braking, by plugging (conduction) with home WALL BOX or public stations and by induction (wireless, in stationary mode) with an original device developed within this project.

6.1 Conduction Charging

Dacia ELECTRON is charged by conduction via a socket located in the lateral rear side, behind the flap of the fuel tank (Figure 9). The recharging time is about 6-8 hours if the battery is fully discharged.

Figure 9: The conductive charging system with home WALL BOX or public station

6.2 Induction charging

The transition from the plug-in to plug-free (wireless) charging through a contactless Inductive Power Transfer (IPT), working in magnetic near-field, besides eliminating the known disadvantages, is considered as the only solution to apply in the near future when driverless technology will become a reality.

The solution applied by us is the SP topology (Figure 10) with a series resonance in primary for increasing the voltage applied to the coupler and a parallel resonance in secondary to get a current generator better adapted to achieve a battery charger. The SP topology ensures satisfactory power transmission efficiency and improves the energy coupling to the secondary side.

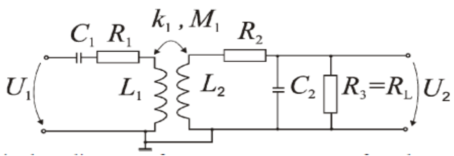

Figure 10: Equivalent diagram of a SP resonant system for a battery charger

Some of the numerical analysis results are confirmed by experimental results obtained in laboratory conditions. The test bench contains (Figure 11): inverter with manual or automatic adjustment options of the frequency in a domain between 10 – 100 kHz; transmitter coil (Tx) and receiver coil (Rx) included in two pads that allow their relative position adjustment; rectifier through which the battery is charged; specific measuring devices.

The supply voltage of the experimental system is obtained from the output of a voltage source inverter. But in the numerical analysis we considered as input voltage a harmonic signal having the same RMS value as the original one.

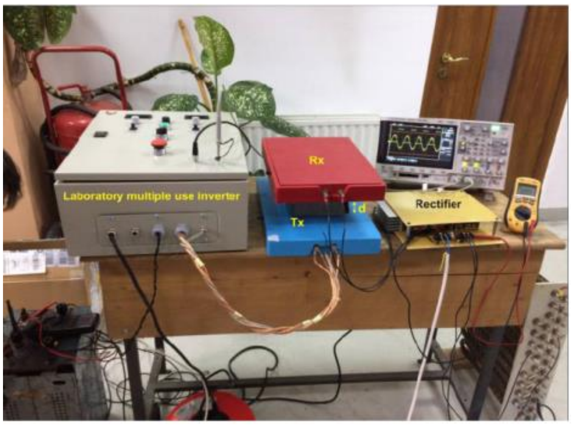

Figure 11: Test bench for EV charger development

If efficiency of primary inverter and secondary rectifier are similar to those of plug-in chargers, the inductive coupler and compensation circuits involved, now form a critical area with a significant share in the overall efficiency in the absence of careful design of their parameters (working frequency but also its variation depending on the distance and mutual position of the coils).

It is based on accurate studies presented in a series of publications [6,7,8,9] who allowed finally to develop and implement the IPT system.

The IPT output characteristics at f = 40.2 kHz (lower splitting frequency) is given in Figure 12 [8].

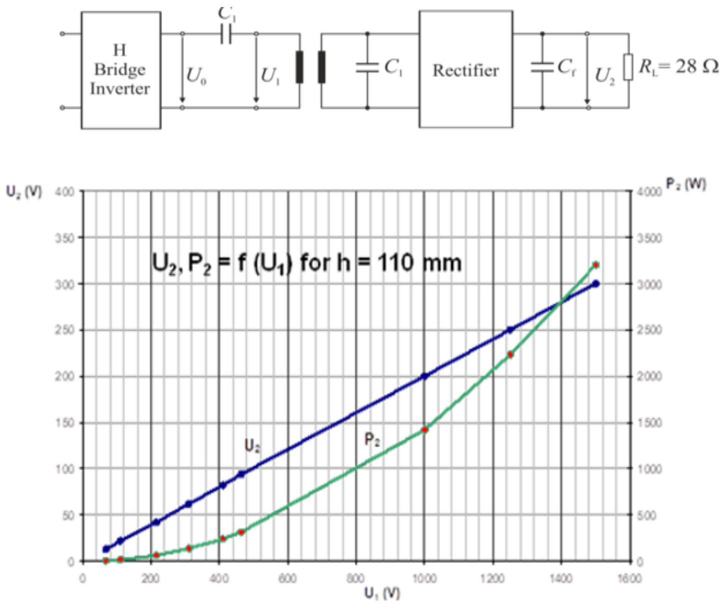

Figure12: IPT Measurement Set-up and output characteristics at f = 40.2 kHz and 110 mm distance between the coils

Here P_2 is the power delivered to load (PDL) for $R_L = 28\ \Omega$ that reaches up to 3.7 kW for 80 mm distance between the coils.

The general scheme of the experimental inductive charging system mounted on the Dacia Electron is shown in Figure 13. The system includes three parts: the Mechanical assembly and the alignment guidance coils; the Ground Transmission Unit assembly with the primary coil and their lift system and the Vehicle Receiver Unit with the Pick-up Rx Pad [5].

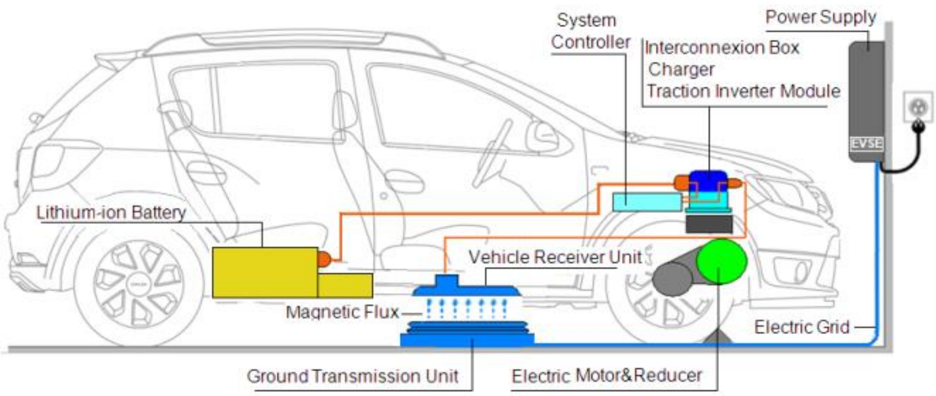

Figure 13: The inductive charging system demonstrator and its implementation on the Dacia ELECTRON concept [5]

With IPT, the charging energy is transferred via a floor transmitter pad to the receiver pad (Figure 14). We use Litz wire (4.1 x4.1 mm^2) planar coils with ferrite flux concentrators to improve the coupling factor. In Figure 15 the Rx pad is integrated on the EV floorpan so as not to reduce the ground clearance.

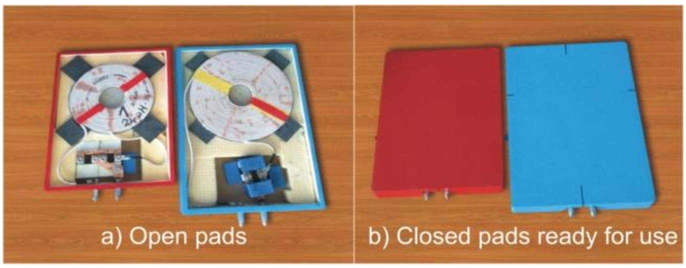

Figure 14: Stationary Tx Pad (blue): 380 x 270 x 40 mm and Pick-up Rx Pad (red): 340 x 260 x 40 mm

Figure 15: Rx Pad integrated on the EV

Prior to charging, an integrated electric motor in the floor plate raises the primary coil in order to improve the power transfer up to 80 mm. The driver can interrupt the charging process. Also, the charging stops automatically when the traction battery is full.

The demonstrator system offers now a variable charging power function of battery SOC with a maximum charging power of 3.7 kW. Recharging time is about 6 hours if the battery is fully discharged.

7 Chassis

7.1 ELECTRON's Suspension

In order to adapt the Dacia ELECTRON to the new weight distribution, the suspension has been revised. The front axle is an independent pseudo Mac Pherson type, with coil springs, hydraulic telescopic shock absorbers and anti-roll bar. The front suspension setting is softer, since electric motors are lighter than all the internal combustion engines available for Dacia SANDERO STEPWAY.

The rear axle is a flexible axle with programmed deflection with coil springs and hydraulic telescopic shock absorbers. The rear suspension has been revised to cope with the heavier weight, due to the presence of the traction battery.

7.2 ELECTRON's Steering

Similar to DUSTER Z.E.RO full electric vehicle we will adapt an electric power steering system, variable rate, column-assist type. This system, a brushed DC motor is integrated in the steering column; the motor is located in the passenger compartment.

Compared with the traditional hydraulic steering systems, with hydraulic pump or electric motor and pump ("power pack") mounted on the Dacia cars, the Electric Power Steering system offers direct assistance to the driver and has the advantages of energy economy, handiness, easy adjustment, less noise, waste and oil pollution.

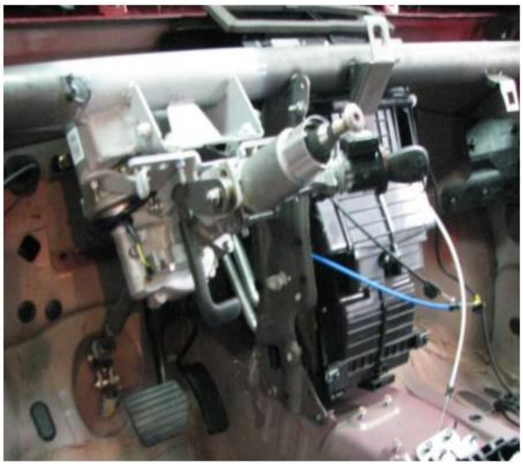

Figure 15: The electric power steering system integrated in the steering column

7.3 ELECTRON's Braking

The braking system is similar to the gasoline version and includes: ventilated discs on the front axle with 280 mm disc diameter, drum in the rear axle 8 inches' diameter and Anti-Lock Braking System (ABS) Bosch 8.1).
For the assist system a new electric type vacuum pump HELLA, was installed in the engine compartment behind the 12V auxiliary battery (Figure 7).

8 The recharging 12V battery system

To recharge the 12 V auxiliary battery, we have used a DC/DC converter 205 V/12 V in the electric mode, to supply the low voltage electric network that fueled, among others, both the "gourmand" auxiliary vacuum electro-pump and the electric power steering. The 12 V battery charger adopted is SWS 1000 L12 from TDK-Lambda France. The characteristics are: input voltage 85-265VAC or 120-350VDC, output voltage 9,6-14,4 V DC, efficiency 84%, operating temperature range – 20 °C to 50° C.

9 MODELLING AND SIMULATION

To simulate the driving and consumption performances of the ELECTRON Concept, the CRUISE software from the AVL, was used. Its modular concept enables free modelling of this experimental vehicle while sophisticated solvers guarantee short calculation times [10].

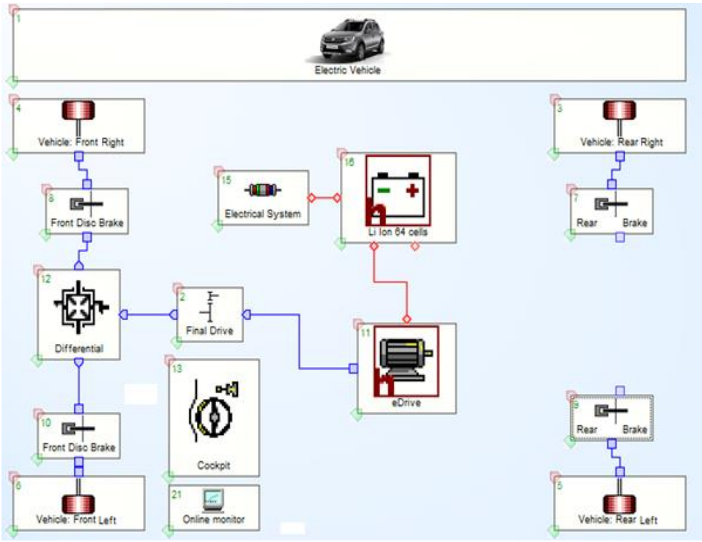

Figure 16: The model of the Dacia ELECTRON FWD with CRUISE software from AVL using for simulating driving performance and energy consumption

The estimated performances of Dacia ELECTRON are: 110 km/h maximum speed, 145 Wh/km energy consumption (NEDC), 105 km autonomy (NEDC) and 6 - 8 h charging time in stationary modes (conduction / induction).

6 Conclusions

This paper presents for the first time the Dacia ELECTRON concept car project, a compact electric vehicle developed within the *Automotive Engineering* Research Centre of the University of Pitesti in order to create a low cost electric crossover car.

This new concept is developed on the Dacia SANDERO STEPWAY II car made by Automobile Dacia - Group Renault. The *AMBRA FWD* electric powertrain was designed based on the experience gained from the project *SEPIA 4WD* used by Duster Full Electric (project Z.E.RO) and from *ELECTRA* E4WD used by Duster Plug in Hybrid Electric Vehicle E4WD (the project Grand Hamster E4WD).

The IPT (Inductive Power Transfer) charging system is designed, built and tested for the first time in Romania. In the near future the IPT system will be refined in relation to the increase of the charging power up to 7.2 kW and the improvement of the EV positioning system.

Our research on this concept will be continued by installing: a new traction battery, 16 kWh, 300V maximum voltage with 36 modules from the Renault ZE traction battery; the 4WD transmission version with robotized gearbox and components from the Duster Z.E.RO; a new 7 kW charging device to achieve the charging at 32A. These devices have been developed in parallel with the ELECTRON concept presented in this paper.

Acknowledgments

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