ACTUAL STAGE OF AN HYBRID UTILITY VEHICLE PROJECT

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Abstract
This paper presents some aspects regarding the construction of the GRAND SANDERO HYBRID UTILITY VEHICLE *concept car. This original vehicle is in progress within the new* Automotive Engineering *Research Centre of the University of Pitesti on the versatile mechanical platform of DACIA-RENAULT LOGAN MCV (*Multi Convivial Vehicle*). The hybrid system, named* EcoMatic Hybrid System *is a parallel two shafts, plug-in type, organized in a motorized solution E-4WD. The thermal powertrain is mounted in front side. In order to reduce the CO_2 emission in the thermal mode, the standard engine Renault 1.6- 16V is fuelled with LPG. The electric powertrain is mounted in rear side in an original solution with an H type axle with a twisted traverse. In order to perform the tests of the vehicle prototype, the electric powertrain and the thermal powertrain the new laboratory Alternative Propulsion System & Renewable Energies will be used. It has a dynamometric roller test bench and an eddy-current engine/motor brake arranged in an original architecture. The* EcoMatic Hybrid System *was developed in such way that allows it's application to the whole Dacia-Renault family cars..*

Keywords: Passenger Car, Plug-in Hybrid Electric Vehicle, Liquefied Petroleum Gas, Photovoltaic Cells

1. INTRODUCTION

In order to achieve an original ecologic vehicle by UPIT to be used in urban and extra urban areas with severe restrictions regarding pollution the ***ECO HUV*** (***ECO****logic* ***H****ybrid* ***U****tility* ***V****ehicle*) project is in progress within the *Automotive Engineering* Research Centre of the University of Pitesti. It is part a of the *EcoLOGIC Programm* strategy (figure 1), foreseen to take place during 2009-2011 period, in *Alternative Propulsion System & Renewable Energies* laboratory.

The concept car (figure 2) was developed on the versatile mechanical platform entitled MCV (Multi Convivial Vehicle) – VAN - Pick-up. It is under construction thanks to a financial aid granted by the Romanian *Ministry of Education, Research and Innovation* [1] and the technical help of the Dacia – Group Renault that has the plant near the city of Pitesti

It will be finalized this year with an operational model whose design is presented in this paper.

In order to achieve an ecologic vehicle the directions were followed are:

- The development of an hybrid electric propulsion system named *EcoMatic Hybrid System* (***E****nergy* ***co****nversion with auto****Matic Hybrid System*)**, parallel two shafts, plug-in type;
- The use of an *alternative fuel*, less polluting for the engine, available at the distribution stations in Romania - LPG (Liquefied Petroleum Gas);
- The added clean energy (solar energy) by using the photovolatic celles mounted on the top of the car;
- Developing of a new A/C system adapted to the thermal fluxes specific to the new propulsion system;
- The development of a experimental research base for laboratory tests and road tests with test benchs and the equipment for vehicles alternative powertrain.

POWERTRAIN TYPE	THERMAL POWERTRAIN	HYBRID POWERTRAIN		ELECTRICAL POWERTRAIN
		THERMAL PREPONDERENCE	ELECTRICAL PREPONDERENCE	
Alternative &Renewable Energies	NGV/Solar	NGV/Electricity	Electricity/NGV	Electricity/Solar
Vehicle application	DACIA ECO GNV	DACIA GRAND SANDERO HYBRID	DACIA ELECTRA+ (Range extender)	DACIA ECO Electra
				

Figure 1: *EcoLOGIC Program strategy for EcoMatic Hybrid System in 2009-2011*

2. CAR BODY AND ARCHITECTURE

The car's body was built based on *DACIA LOGAN MCV and DACIA SANDERO* components.
Unlike the model of the *DACIA Logan MCV* (first phase) from which was started, the new vehicle body was changed in the front side and in the rear side; this is the first novelty of the project.

After performing a benchmarking in the HEV field [2], the chosen architecture for the experimental *GRAND SANDERO HYBRID* vehicle is a parallel system type, with torque addition and with two shafts.
Due to the geometric restrictions of the base vehicle, the organization of the hybrid propulsion equipment (figure 3) is done by dividing it in two parts (motorized solution E- 4WD).

Figure 2 : *DACIA GRAND SANDERO HYBRID*, concept car fueled whith LPG and electrcity

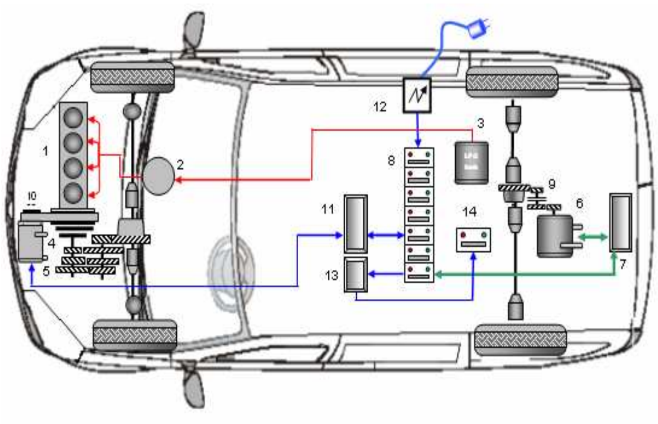

Figure 3*: Architecture of the GRAND SANDERO HYBRID*
1 Engine; 2 LPG System; 3 LPG Tank; 4 Clutch; 5 Gearbox; 6 Electric Motor/Generator; 7 Control Motor; 8 Traction Battery; 9 Rear Transmission; 10 Generator; 11 Control Generator; 12 Battery Charger; 13 DC/DC converter; 14 Starting battery

The advantages of this design layout are:

- Minimum modifications upon the base vehicle, which give us the possibility of using it in ordinary traffic – urban or not – in order to perform road tests;
- The reduction of the electric equipment's geometric restrictions (electric motor, electronic control unit, traction battery) regarding type, mass and global dimensions;
- Flexibility in choosing the electric motor through the possibility of tuning its characteristics with vehicle's demand by using a reduction unit with constant transmission ratio;
- Capitalizing the all wheels drive (E-4WD, part time).
- Reducing shocks to change modes of the operation (of the electric mode in a thermal mode and vice versa) because of the "elastice" link between the axle driving and the road.

According to the preliminary specifications, the operational *GRAND SANDERO HYBRID* vehicle will have the following operational main modes (figure 4):

- ***Parking*** and ***traction battery recharging*** (plug-in), (1);
- ***Starting*** (2,11) and ***running*** (3)**,** with low to mid-range speed in the *electric mode*, when the electric motor takes its energy from the traction battery. This operational mode is non-pollutant traction and occurs on short distances in urban driving conditions. The maximum speed is set by the power of the motor;

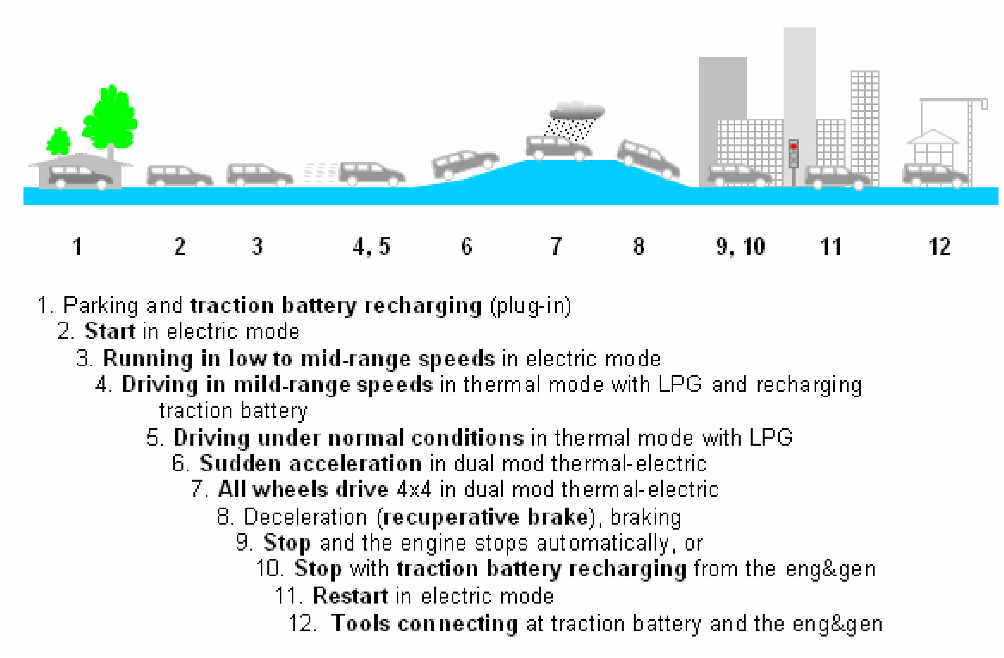

Figure. 4. *Driving and operation of the GRAND SANDERO- Hybrid Utility Vehicle (final stage)*

- ***Driving under normal conditions*** (4), in the *thermal mode*, which ensures performances (acceleration, autonomy, etc) close to the base vehicle. Moreover, when driving at low loads (5), by recharging the battery the engine specific load is increased, thus improving the engine efficiency;
- ***Sudden acceleration*** (6), in the hybrid mode, which ensures increased dynamic performances by simultaneous operation of both engine and motor. The speed range in the hybrid mode depends upon the motor power, the operational rotational speed range and the rear transmission ratio;
- ***All wheels drive*** (7), in the *hybrid mode E 4WD*, which ensures increased drivability on the slippery roads;
- ***Regenerative braking*** (8), when decelerating by replacing the classical engine brake with a process of transforming the vehicle's kinetic energy in electric energy, reusable afterwards to the acceleration process. This is made by the operation of the electric motor as a generator.
- ***Stop and the engine stops automatically*** (9), negating the fuel consumption and pollutant emissions;
- ***Stop with traction battery recharging*** (10) from the eng & gen, if the energy level of the battery is low;
- ***Tools connecting at traction battery and the eng&gen*** (12), an operation mode of the Hybrid Utility Vehicle allowing supplementary functions absent to other utility vehicles.

3. THE THERMAL POWERTRAIN DESIGN

The thermal propulsion equipment *Eco LPG* of the *EcoMatic Hybrid System* is in standard solution composed by a 1.6 liters, Renault K4M engine of 115 hp @ 5700 rpm and a mechanical transmission with 5 gears. In order to reduce the level of the engine's pollutants, we have chosen the LPG fuelling system. Taking into consideration that Dacia – group Renault doesn't use LPG in mass production for the K4M engine, this is the second novelty of the project [3].

The LPG fuel system chosen is a multi-point sequential *OMEGAS* type, *LANDI RENZO* made.The LANDI RENZO OMEGAS phased sequential system adopted for the prototype is part of the latest generation of petrol to gas phase LPG conversion systems on the market. The principle used by the gas ECU in order to determine the injection times for the gas injectors is based on the acquisition, during the gas operation of the petrol injection times on emulation impedances internal to the gas ECU itself .

Figure 5:. *DACIA GRAND SANDERO HYBRID LPG -electricity with Renault K4M-690 1,6 liters-16V engine fuelled with LPG by Landi Renzo OMEGAS installation*

This means that the control of the motor is left to the petrol control unit while the gas control unit is given the task of converting the data generated by the former for the petrol injectors, into suitable data for the gas injectors.

To put it in simple terms, one could say that the gas control unit converts a certain quantity of energy that should have been released from petrol into a corresponding quantity of energy that will be really released by the gas.

The result is that the system is as uninvasive as possible compared with the original petrol system and is able to integrate effectively with the latter's main (controlling fuel ratio, cut off, EGR, purge canister, cut off for over-revving, etc.) and secondary (air-conditioner clutch control, power steering overpressure, electrical loads, etc.) functions.

The conversion of petrol injection times in gas injection times is carried out on the basis of a series of parameters (input signals), in addition to the petrol injection times acquired by the gas ECU: MAP pressure signal, petrol injection signals, engine coolant temperature, engine revolution, gas temperature and pressure, battery voltage.

The specific constraints of the LPG injection system's manufacturer (LANDI RENZO), the ones of the vehicle's manufacturer (DACIA-RENAULT) and the actual legislative regulations were taken into consideration when performing the organization of the layout. Fixing of some components (e.g. the tank-multivalve assembly, figure 6) was influenced also by the adopted architecture of the electric power train, which will be used on the *GRAND SANDERO HYBRID* together.

4. THE ELECTRIC POWERTRAIN DESIGN

The electric propulsion equipment system is developed on the rear axle of the vehicle. It includes an AC induction motor (asynchronous motor type) and a mechanic transmission (reduction & diferential gearbox), (figure 6).

The motor-transmission assembly is mounted semi-elastic in three points on the vehicle's rear structure.

The motor , 200-150W liquid cooled, is made by MES-DEA – Swiss. The performances are: in continuous mode: 18 kW (24,5 hp), 90 Nm @ 2850 rpm; in peak mode: 31 kW (42 hp), 160 Nm @ 1400 rpm [9].

The control of the electric motor is also made by MES-DEA – Swiss. The TIM (Traction Inverter Module) 400 type is a vector control AC motor drive, especially designed for electric and hybrid vehicles.

Figure 6: The AC induction motor with reduction & differential gearbox made by MES-DEA

The rear axle (figure 7) designed for the *GRAND SANDERO HYBRID* is an H type axle with a twisted traverse. It has been design by using the CATIA CAD/CAE software starting from the original rear axle of the Dacia Logan MCV.

There has been added a wheel hub compatible with the drive axle features. Another modification of the original rear axle was to change the inferior fixation points of the dampers. This had to be done in order to obtain the necessary space for the final drive shafts.

The final drive shafts make the connection between the reduction and differential unit and the rear wheels hub. They are jointed by means of axial- angular couplings.

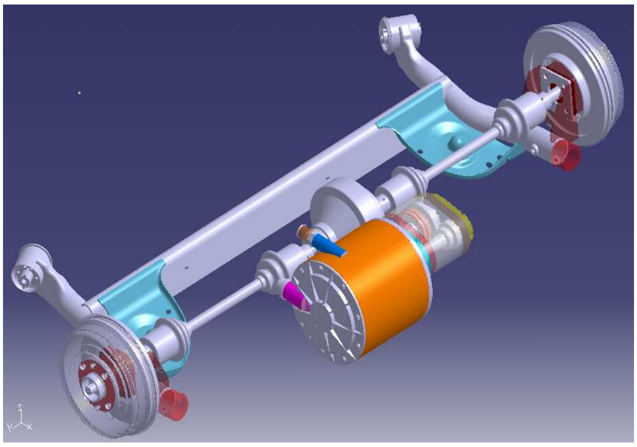

Figure 7: *GRAND SANDERO HYBRID rear axle and electric powertrain – CATIA modelling*

For decoupling the electric motor la viteze de peste 100 km/h we have given an automatic hydromechanical system [3].

The electric equipments needed for electric energy generating/storing/plug-in to the home electric network include a traction battery, lithium-ion technology, 216V, an embarked AC/DC charger and a DC/DC converter for convert high voltage to 12 Volts for storing in the auxiliary battery.

This equipment is completed by an assembly of photovoltaic cells placed on the roof (figure 8).

Figure 8: *GRAND SANDERO HYBRID with photovoltaic* cells placed on the roof

It is connected only to the low voltage circuit (12V) which supplies the auxiliary preconditioning outfit of the vehicle interior.

All these equipments will be purchased in the period immediately following the finalization of the complete model vehicle and performance simulation software AVL Cruise.

5. SPECIFIC AUXILIARY SYSTEMS

In order to maintain the driving comfort, the hydraulic system used to assist the steering available on *Dacia Logan Diesel* (1,5 dci), a system with electrical pump group, was adapted.

To maintain the braking comfort a vacuum electro-pump specially manufactured for EVs was used.
To reduce consumption of electricity of the lighting lamps, the incandescent light bulbs, were replaced with LED's.

The operation of the system is visualized by the driver in real time on a 7” color and multitasking display (figure 9).

The energy flows (electrical and mechanical) is illustrated on this display. Other information such as battery state of charge, LPG instantaneous consumption, and load distribution between the two power sources when operating as a hybrid vehicle is to be displayed on the screen.

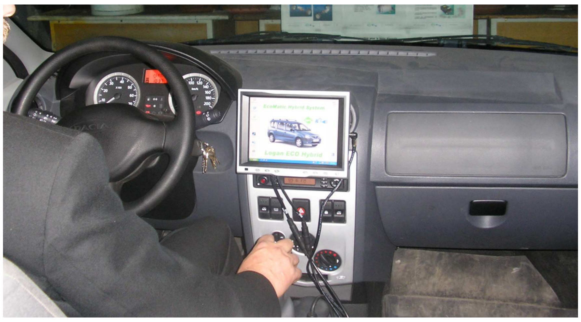

Figure 9: *Multitasking display used to illustrate the energy flows in the EcoMatic Hybrid System*

6. OPERATION MODES

For the base version of GRAND SANDERO HYBRID, featuring a primitive PTMU (Power Train Management Unit), which is to be finalized in 2009, the following operating modes will be available:

- Parking and traction battery recharging (plug-in);
- Start and running in low to mid-range speeds in electric mode;
- Driving under normal conditions in thermal mode with LPG;
- Regenerative brake.

The pure electric mode is commanded by pushing the ZEV button [3]. In this case, the command of the electric motor, which drives the rear wheels, is ensured by the electrical acceleration pedal featuring a potentiometer sensor.

In thermal and hybrid modes, this pedal is used for commanding the thermal engine, as well; it is thus about the drive by wire type of commands. In ZEV, the Air Conditioning is no longer available. The pure thermal operating mode is imposed by using a specific switch on which highway is written. In this case, the electric motor isn't coupled with the rear wheels of the vehicle.

In order to ensure an efficient working of the two power sources, a coupling-decoupling system was designed for reducing the energetic losses caused by the specific inertia of these two power sources. It is a hydraulic type and is commanded by a control unit according to different input parameters.

The coupling of the electric motor is done after canceling the thermal mode and is preceded by synchronizing the movement of the elements to be driven by imposing the start of the electric motor which drives the primary shaft and the free gear from the secondary shaft. The elements' speeds which are to be coupled are measured with an inductive sensor, which measures the primary shaft speed and Hall type sensor, which measures the rear axle differential shaft speed.

7. MODELLING AND SIMULATION

To simulate the driving and consumption performances of *GRAND SANDERO HYBRID*, CRUISE software, recently received from the AVL, was used.

It's modular concept enables free modelling of all possible vehicle configurations while sophisticated solvers guarantee short calculation times [10].

CRUISE is typically used in drive train and engine or motor development to calculate and optimize the following:

- Fuel Consumption and Emissions;
- Driving Performance (acceleration, elasticity);
- Transmission Ratios;
- Braking performance and for the determination of collective loads for stress calculations and drive train vibrations.

The modular structure of CRUISE permits modelling of all existing and future vehicle concepts for both single and double track vehicles (motorcycles, passenger cars, trucks, etc.).

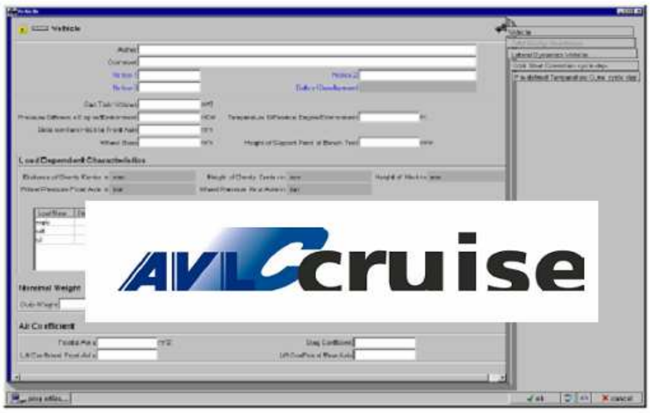

Figure 10: *The CRUISE software from AVL using for modeling ECU HUV and simulating driving performance and energy consumption*

8. TECHNICAL CONCEPT OF THE TEST BENCH

In order to perform the tests of the alternative vehicles (HEV's, EV's,) or propulsion system for automobiles fuelled by alternative and renewable energies at the *Automotive Engineering* Research Centre of University of Pitesti a new laboratory is under construction [5].

It has:

- A SCHENK roller test bench adapted for testing the electric and hybrid electric vehicle;
- A HOFFMANN Eddy-current engine/motor brake for testing the performances of engines, motors and hybrid power train systems.

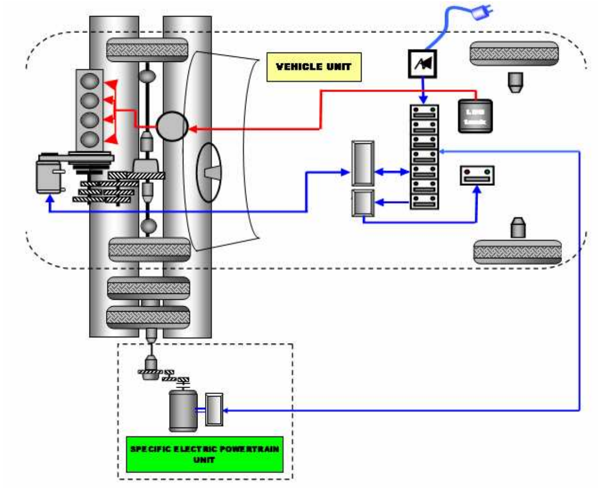

Figure 11*: The EcoMatic Hybrid System arranged in an original architecture for the dynamometric rollers test bench*

In order to test the *GRAND SANDERO HYBRID* prototype on dynamometric chassis of the *Research Centre Automotive Engineering*, a new architecture of the *EcoMatic Hybrid System* was designed (figure 11). a new architecture of the *EcoMatic Hybrid System* was designed (figure 12).

Figure 12*: The test bench for hybrid electric and electric vehicle under construction in the Alternative Propulsion System & Renewable Energies laboratory, Automotive Engineering Research Centre, University of Pitesti*

The adaptation of the system with two driving axles to the roller test bench featuring only one pair of rollers has been made by transforming the rear axle into driven one with the aid of the electric propulsion system. This false axle is mounted on the bench in a parallel way with the front axle of the vehicle.

In such a configuration, on the roller test bench will be performed tests in order to simulate either the standard driving cycles or other types of cycles (figure 13).

Thus, the system will be optimized and tested in order to find its performances regarding fuel consumption (LPG, gasoline), electricity, autonomy and some dynamic performances as well.

In order to test the prototype on the road for measuring the dynamic performances of the vehicle, within longitudinal movement, there has been necessary to accomplish an assembly of specific equipments.

It consists of a DATRON CORREVIT equipment (figure 13) with optical sensor and a personal computer - onboard vibration resistant - dedicated to be used for data acquisition system and specific sensors.

Figure 13*: The DATRON CORREVIT equipment for measuring the dynamic performances of the vehicle on the road*

The non-contact, optical sensor system made by CORRSYS-DATRON provides a superior solution for the measurement of speed, distance, and other dynamic measurement variables. The operation of the system is visualized by the driver in real time on a 7” colour and multitasking display.

9. Conclusions

The *ECO HUV* (*ECOlogic Hybrid Utility Vehicle*) project in development in the new *Alternative Propulsion System & Renewable Energies* laboratory, part of *Automotive Engineering* Research Centre, University of Pitesti has offered an experimental platform for research hybrid electric propulsion system for the urban automobiles.

The *ECO HUV* prototype presents 4 novelties:

- New body named GRAND SANDERO;
- LPG fuelling of the K4M engine, which is not in the mass production at Dacia site, as stated before;
- The hybrid propulsion system of parallel type E-4WD featuring a low level PTMU;
- Photovoltaic cells placed on the roof connected to the low voltage circuit (12V) which supplies the auxiliary preconditioning outfit of the vehicle interior.

The EcoMatic Hybrid System was developed in such way that the concept may be applied to the Dacia Logan VAN, Pick-up platform, as well.

Our research on this subject will be continued by the following steps:

- Implementation of the CNG fuelling system;
- Adaptation of an improved PTMU able to extend the operating modes as illustrated in figure 4.

The research laboratory with an dynamometric testing roller benchmark, engine benchmark and road testing equipments, will allow the development of future projects regarding the ecological propulsion of the vehicles and the extension of the cooperation with other interested team, having similar research objectives.

Acknowledgments

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