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ECO HUV- ECOlogical Hybrid Utility Vehicle

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Abstract

This paper presents some aspects regarding the construction of the *ECO HUV* (*ECOlogical Hybrid Utility Vehicle*) concept car. This original vehicle, named *GRAND SANDERO HYBRID,* presented for the first time in this paper, 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, transversally classic position. 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, PHEV (Plug in Hybrid Electric Vehicle), Parallel HEV

1 Introduction

In order to achieve an ecologic vehicle to be used in urban and extra urban areas with severe restrictions regarding pollution the ***ECO HUV*** (***ECO****logial* ***H****ybrid* ***U****tility* ***V****ehicle*) is in progress within the *Automotive Engineering* Research Centre of the University of Pitesti. It is part a of the *EcoLOGIC Program* strategy (figure 1), foreseen to take place during 2009-2011 period,

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

Figure 2 : *DACIA GRAND SANDERO HYBRID* , concept car with an original body and *EcoMatic Hybrid System* under construction in the *Automotive Engineering* Research Centre, University of Pitesti

in *Alternative Propulsion System & Renewable Energies* laboratory.

The concept car (figure 2), first time presented with the new body in this paper, 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 on the original MCV platform, two directions were followed:

- The development of a *plug-in hybrid electric propulsion system*, named *EcoMatic Hybrid System* (***E****nergy* ***co****nversion with auto****Matic*** ***Hybrid System***), for reasons of optimizing the global operation of the vehicle;
- The use of an *alternative fuel*, less polluting for the engine, available at the distribution stations in Romania - LPG (Liquefied Petroleum Gas).

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 (figure 2); 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).

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).

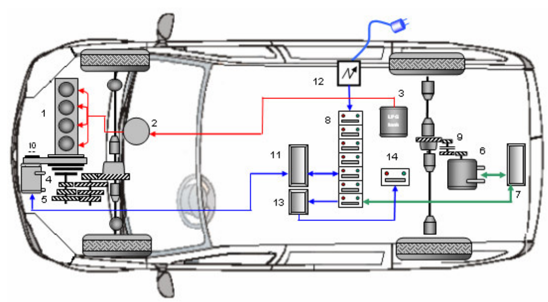

Figure 3: Architecture of the ECO HUV GRAND SANDERO HYBRID

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

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);

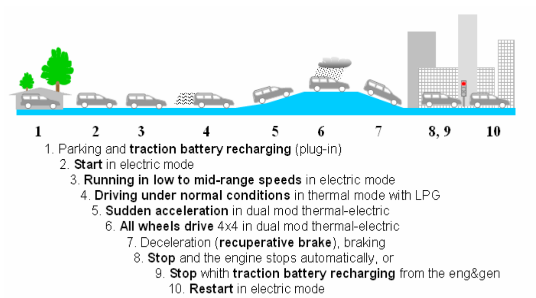

Figure 4. Driving and operation of the *GRAND SANDERO HYBRID* (final stage)

- ***Starting*** (2,10) 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;
- ***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, by recharging the battery the engine specific load is increased, thus improving the engine efficiency;
- ***Sudden acceleration*** (5), 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*** (6), in the *hybrid mode*, which ensures increased drivability on the slippery roads;
- ***Regenerative braking*** (7), 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.
- ***Recharging*** traction battery from the eng&gen.

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).

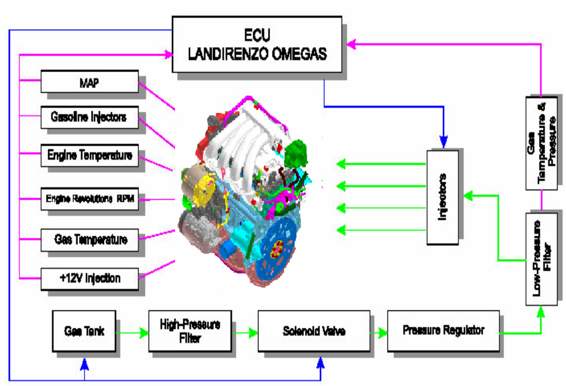

Figure 5**:** ECU LANDI RENZO OMEGAS for the engine *ECO GPL* *by UPIT*
(Renault K4M engine 1,6 liters, 16V)

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

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

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 *Eco ELECTRA* system is developed on the rear axle of the vehicle. It consists of the motor asynchronous type and the mechanic transmission, which adapts the energetic and kinematics parameters of the motor to the driving conditions; it also provides the mechanical energy to the rear wheels.

The motor-reduction unit-differential assembly is mounted semi-elastic in three points on a common frame with the one of the towing hook. This frame is attached to vehicle's rear structure of resistance.

The motor is made by MES-DEA – Swiss, asynchronous type, 16 kW (22 hp) of continuous power, 60 Nm @ 2850 rpm, liquid cooled. The control of the electric motor is also made by MES-DEA – Swiss. The TIM (Traction Inverter Module) is a vector control AC motor drive, especially designed for electric and hybrid vehicles.

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*.

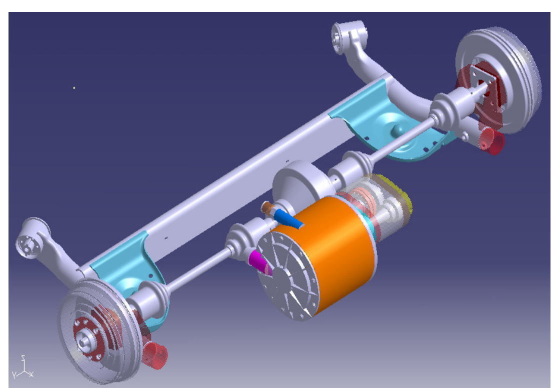

Figure 7: Rear axle and electric powertrain ECO ELECTRA– CATIA modelling

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

Figure 8: Electric powertrain ECO ELECTRA mounted in the rear side of the vehicle. Working on the mule vehicle

in order to obtain the necessary space for the final drive shafts.

The *Eco ELECTRA* transmission is manufactured as a prototype and consists of the reduction unit-differential assembly mounted in a common case made by light alloy and the shafts, which transmits the electric power to the rear wheels.

The reduction unit-differential assembly was designed to have only one gear ratio. On the other hand, in order to have flexibility to the mounting of a standard electric motor and to offset it from the shaft of the final drive, we have decided to use the three shafts transmission: the primary shaft, the intermediary shaft (equipped with the mechanism of decoupling the motor at high speeds) and the secondary shaft (the shaft of differential). All shafts are in the same plan. The gear wheels feature helical gears.

The differential, in a classical design, is integrated into the gear reduction unit in a common case manufactured by light alloy.

The final drive shafts make the connection between the gear reduction unit - differential assembly (mounted pseudo-elastic on vehicle’s body) and the rear wheels hub. They are jointed by means of axial- angular couplings.

For decoupling the electric motor we have given a hydraulic system based on a double effect cylinder (13, figure 10), which acts on the mechanism (12, figure 10).

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 cell placed on the roof. At first this 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.

To enhance manoeuvrability (for vehicle parking) a version of a rear axle with steer able wheels actuated electro-mechanical is under construction.

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

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

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.

6 Operation modes

For the base version of LOGAN ECO 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. 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 hydraulic schema of this system is presented in figure 10.

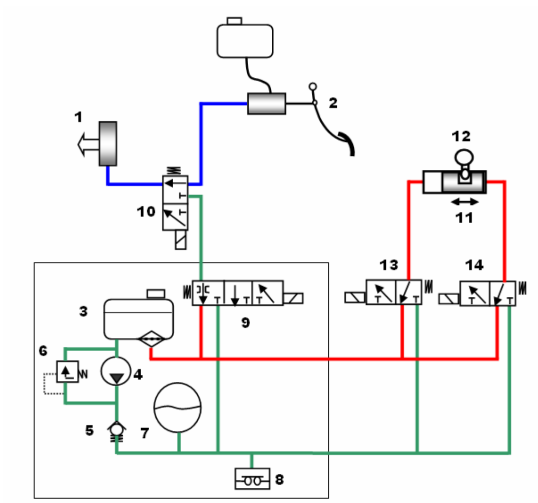

Figure 10. The hydraulic schema used to command the clutch of the thermal powertrain and the coupling/decoupling mechanism of the motor

When starting and driving the vehicle in electric mode, the thermal engine is decoupled from the front transmission thanks to an automatic clutch (in the case the selector lever is not in the Neutral position). Certainly, this will reduce the inertia of the thermal components.

In thermal mode, at steady driving at high speeds, the system decouples the electric motor thanks to a coupling/decoupling mechanism mounted on the secondary shaft of the rear gear box. Aside of reducing the electric equipments inertia, this mechanism avoids over-speeding of the electric motor.

When decelerating, after driving in thermal mode, the system decouples the thermal engine through the automatically clutch. This increases the process of recuperating the energy in these operating periods.

The automatically decoupling/coupling of the thermal engine is made by a part of the new system (figure 10), which acts upon the simple effect cylinder 1 of the clutch in parallel with the classical hydraulic system (commanded through pedal 2) of the standard Logan MCV 1.6 l - 16V. It is enabled only in the case of decelerating felt by releasing the acceleration pedal and authorized only when the brake and clutch pedals aren't pushed.

It is thus possible the transforming of dissipative type "thermal engine brake" into "electric motor brake" because the latter operates as generator. The system uses an electro-hydraulic assembly composed by tank featuring filter 3, electro-pump 4, one way valve 5, discharging valve 6, pressure accumulator 7, presostat 8 and control flow electro-vane 9. These are mounted on a hydraulic block, which integrates the hydraulic circuits.

The coupling of the assembly (taken from mass production, being used in order to drive the clutch) to the vehicle's hydraulic system is done through the electro-vane 10.

The decoupling the electric motor is made by commanding the button which imposes the thermal mode. This occurs at high speeds. The system decouples the electric motor through the double-effect type hydraulic cylinder 11, which acts upon the coupling/decoupling of the gear box 12.

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.

The supply with pressurized liquid to the working chambers of the cylinder 11, corresponding to the coupled or decoupled state of the electric motor is done by the electro-hydraulically assembly thanks to the electro-vanes 13 and 14, which are commanded by the control unit as “all or nothing”.

7 Modelling and simulation

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

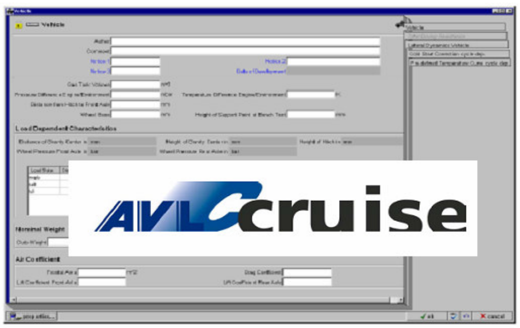

Figure 11: The CRUISE software from AVL using for modeling ECU HUV and simulating driving performance and energy consumption

It’s modular concept enables free modelling of all possible vehicle configurations while sophisticated solvers guarantee short calculation times [6].

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;
- 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.).

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.

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 12, left).

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 (figure 12, right).

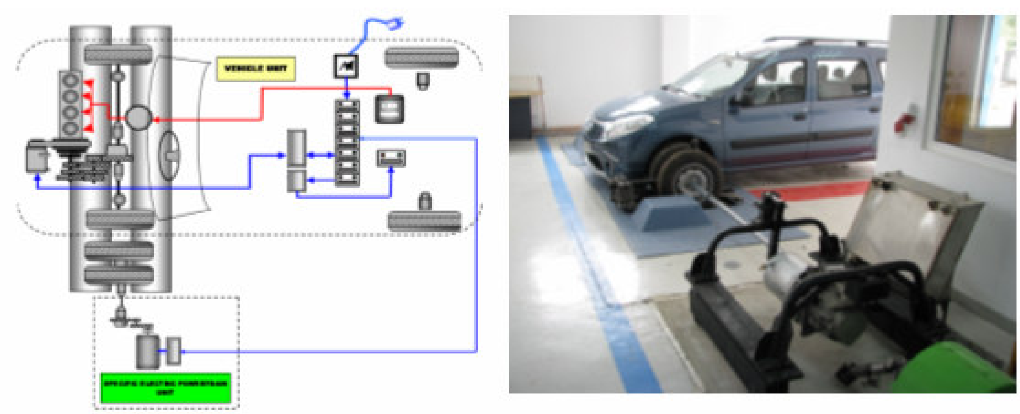

Figure 12: The test bench for hybrid electric and electric vehicle under construction in the *Alternative Propulsion System & Renewable Energies* laboratory, *Automotive Engineering* Research Centre, University of Pitesti

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. 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 tree 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.

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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