MULTI-ARCHITECTURE / MULTI-APPLICATION MODELLING APPROACH FOR HYBRID ELECTRIC VEHICLE USING ENERGETIC MACROSCOPIC REPRESENTATION

Daniela CHRENKO(a), Shiyu GAN(b), Phillipe BOUILLOT(c), Luis LE MOYNE(d)

(a,b,d)ID-MOTION DRIVE EA 1859, Univ. Bourgogne Franche Comté, F58027, Nevers, France
(b,c)SODEMO Moteurs, Technopole du Circuit BP 37, 58470 Magny-Cours, France

(a)daniela.chrenko@u-bourgogne.fr, (b)shiyu.gan@sodemo.com, (c)philippe.boulliot@sedomo.com,
(d)luis.le-moyne@u-bourgogne.fr

ABSTRACT

Hybrid vehicles are among the most promising solutions for a sustainable mobility. Among the multitude of hybrid architectures three architectures seem to be equally promising (series, parallel and series/parallel) and it is possible to find them in a multitude of applications like motor bikes, city- and family-cars as well as busses. Each application needs an adapted control strategy. The most important tool in the development of control strategies is a well configured model. This article presents a multi-architecture/multi-application model for hybrid vehicles using energetic macroscopic representation and inversion based control design. This approach is successfully used to evaluate the power split and fuel consumption of different vehicles on different driving cycles.

Keywords: hybrid electric vehicles (HEVs), hybrid architecture, energetic macroscopic representation (EMR), energy management

1. INTRODUCTION

The limitation of crude oil resources and the global warming due to greenhouse gas emissions emphasis the need to develop more fuel efficient and cleaner solutions for all sectors of road transportation. Hybrid Vehicles are among the most promising approaches to maintain our mode of personal and individual transportation. A hybrid electric vehicle (HEV) uses two or more different energy sources, storages or converters from which at least one has to deliver its energy in electric form (Guzzella & Sciarretta 2010). Goal of hybridization is to use all propulsion components in their best efficiency regions in order to improve the global efficiency of a vehicle. The large definition of HEVs leads to a multitude of technical solutions with regard to degree of hybridization as well as hybridization architecture and for the moment no solutions shows a considerable advantage. At the same time individual transportation is a broad field not only dominated by the multitude of cars existing, but compromising also two wheelers (scooters and motor bikes) and in a broader sense busses and race cars as technology showcase.

In the product development modeling gets more and more important as it allows the acceleration of multiple aspects of the development as for example the component dimensioning, packaging and design. The entire automotive V-development process (Prechelt n.d.) is accompanied by models with a different degree of detail. Amongst them, the vehicle model is an important tool for the development of system control, especially the energy management. As the advantage of hybridization is strongly linked to the global efficiency, a well-adapted system control is required. Moreover, hybrid system energy management development requires the availability of a system model that can be run in real time, therefore a tradeoff has to be made between model accuracy and calculation time (Kutter & Bäker 2010).

Goal of this work is to develop a generic approach that is capable to represent different hybrid architectures in one single model parameterized accordingly and to use this approach in order to develop energy management strategies.

Energetic Macroscopic Representation (EMR) is a representation tool, capable to visualize complex systems and well adapted for inversion based control design.

In the following section different vehicle architectures and control approaches are presented. Section 3 introduces EMR, the development of a generic hybrid vehicle model and inversion based control design. Results of this approach for different vehicles are discussed in section 4. Conclusions and Perspectives are given in section 5.

2. HYBRID VEHICLE ARCHITECTURES

Hybrid vehicles can be classified according to the degree of hybridization into Micro-HEV, Mild-HEV and Full-HEV (Marc et al. 2010) or according to the power train architecture as Series-HEV, Parallel-HEV and Complex-HEV. If a hybrid electric vehicle can be recharged by connecting a plug to an external electric power source, it can be called a plug-in HEV. Likewise, if an electric vehicle contains a range extender (it is usually an ICE) in order to increase the electric vehicle driving autonomy, we can call this type of vehicle an Extended-range electric vehicle (EREV) (Tingting 2011).

2.1. Architectures

Series Hybrid: In series hybrids, only the electric motor drives the drivetrain, and a smaller ICE works with a generator to power the electric motor or to recharge the batteries. They also usually have a larger battery pack than parallel hybrids, making them more expensive. Once the battery charge is low, the combustion engine can continously generate power at its optimum settings. As soon as the battery charge is sufficient, the combustion engine is switched off making the hybrid system efficient in extensive city driving (Asus et al. 2013). The series hybrid structure has always been used in the frequent start/stop driving situation such as the city bus, Volvo B5L and Gemini 2 HEV are commercially available series full-HEV (Wikipedia n.d.).

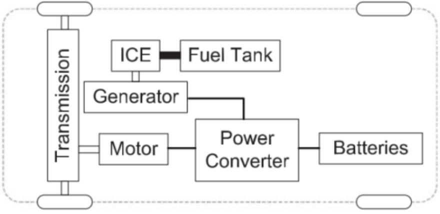


Figure 1: Series Hybrid Configuration

Parallel Hybrid: In parallel full-HEV, the ICE (internal combustion engine) and EM (electric machine) are mechanical coupled and can both deliver power in parallel to the wheel. A parallel HEV is capable of improving the overall efficiency to 43.4% (Tie & Tan 2013). Parallel full-HEV, compared to series HEV, have a lower battery capacity. One of the advantages of parallel full-HEV is that the EM and ICE complement each other during driving. This makes the parallel full-HEV a more desirable vehicle under both highway-driving and city-driving conditions. As compared to series full- HEV, parallel full-HEV has higher efficiency due to smaller EM and battery size. (Tie & Tan 2013).

Honda Insight, Honda Civic Hybrid and Ford Escape are commercially available parallel full-HEV.

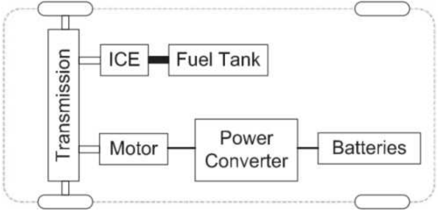


Figure 2: Parallel Hybrid Configuration

Series-Parallel Hybrid: The series–parallel full-HEV drive train employs two power couplers that are mechanically powered and electrically powered. Although it possesses the advantage of series full-HEV and parallel full-HEV, it is relatively more complicated and costly. For the Series-parallel hybrid vehicle, there are 2 possible approaches for the transmission: Electric-Variable-Transmission (EVT) and Planetary-gear-set (Ifak & Iml 2015). The objective of these 2 combinations is to operate ICE at the optimum working point which means at its optimum rotational speed and torque. For series–parallel full-HEV, they are more flexible with regard to their control strategies than the other two configurations.

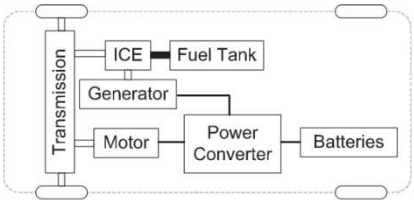


Figure 3: Series-Parallel Hybrid Configuration

Toyota Prius, Lexus LS 600h, Lexus CT 200h and Nissan Tino are commercially available series–parallel full-HEV (Ifak & Iml 2015).

Complex Hybrid: A multitude of other hybrid architectures exist as for example the electric turbocharging (e-Turbo) used in Formula 1 race cars or Le Mans prototypes (Le Mans 2012). Those other architectures are classified as complex hybrids.

2.2. Control Strategies

The energy management strategy of a hybrid vehicle is extremely important as it decides how and when energy will be provided by the various sources of HEV. A control strategy for a PHEV does not necessarily provide maximum fuel savings over all driving demand (Amjad et al. 2010). *Zhang et al.* present an extensive overview of the state of the art control strategies for Hybrid vehicles and classify them in detail which include rule based strategies and optimization based strategies (Zhang et al. 2015). In rule based control strategies, the determined and fuzzy logic strategies have been considered. And in optimization based control strategies, transient and global strategies are included. A similar work has been provided by *Chrenko et al.* (Chrenko et al. 2015).

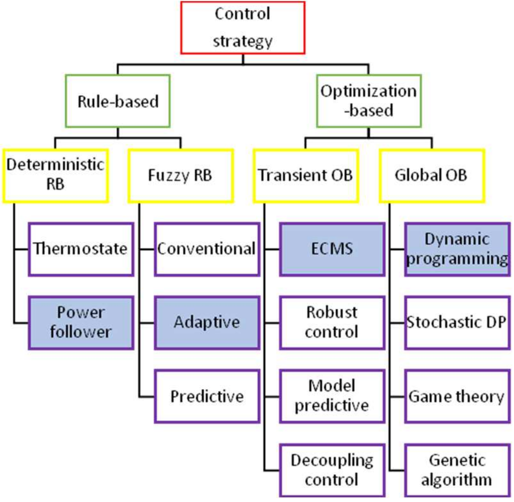


Figure 4: Classification of Control Strategies

Rule based strategies: The primary aspect involved in rule-based power management approaches is their effectiveness to instantly control the power flow in every kind of hybrid powertrain. The rules are determined by heuristics, intuition, human expertise and actually mathematical models and normally, without a priori familiarity with a predefined driving period. These strategies can possibly be classified into deterministic and also fuzzy rule based approaches. The main idea associated with rule based strategies is to move the actual ICE operating point as close as possible to some predetermined value for each and every instant in time in the vehicle operation. If the best efficiency should be used, the vehicle operation points will be forced in the vicinity of the best point of efficiency at a particular engine speed. The resulting power differences, which can be positive or negative, are contributed simply by EM (Asus et al. 2014).

Optimization Based Strategies: In optimization-based control strategies, the reference of the optimal torques and optimal gear ratios can be found by minimizing a cost function of fuel consumption and/or emissions. Global Optimization strategy needs the information of the whole driving cycle which includes the driving speed, acceleration, stop numbers and times, as well as the traffic conditions. The **global OB** can be a good reference for other control strategies. However, with global OB control techniques, real-time energy management is not directly possible.

However, on the basis of an instantaneous cost function, a control strategy based on a real time optimization can be obtained. This instantaneous cost function relies on the system variables at the current time only and also, to maintain the battery SOC with a certain range of variation, it should include equivalent fuel consumption. This control strategy is referred to as **transient OB**.

3. ENERGETIC MACROSCIPIC REPRESENTATION (EMR)

3.1. Introduction

Based on the energy-flow analysis in multi-physics systems, a new representation has been developed by a French research team from the L2EP (a laboratory from University for Sciences and Technologies of Lille) namely Energetic Macroscopic Representation (EMR). Such a representation has been used to propose a synthetic description of electromechanical conversion system, but can be today extended to other types of conversion system where the energy flows have to be managed between more than two sources of different nature (electrical, thermal engine, electrochemical source), through complex paths (Barrade & Bouscayrol 2011).

EMR representation is a synthetic graphical tool based on the principle of action and reaction between connected elements. Components can be internally described by causal ordering graphs, or other descriptions such as transfer functions, Petri nets, state models, bond-graphs (Lhomme et al. 2004). EMR representation allows an upgrade of dedicated sub-models, like the battery model, without the need to change the rest of the model.

The EMR is not only useful for the synthetic representation of complex systems but also for the deduction of an Inversed Based Control scheme (IBC) which is directly obtained from the EMR through specific inversion rules. The IBC leads to a control structure with a maximum number of operations and measurements. Then the final control implements results from simplifications applied on the IBC.

The EMR is based on three kinds of elements which describe the physical state of a component.

Source elements (green oval pictograms) produce state variables (outputs). They can be either generators or receptors. They are disturbed by reactions of other elements.

Conversation elements ensure energy conversion without energy accumulation (power converter, gear box, etc…). They have eventually tuning inputs (red pins) to adjust the conversion between input (action) and output (reaction) variables. Depending on the nature of the conversion, they are depicted by rectangular or circular pictograms. The rectangular pictogram is used for mono-physical conversion (eg. electrical to electrical). The rectangular pictogram is used for multi-physical conversion (eg. chemical to mechanical).

Coupling elements allow the representation of energy distribution (parallel connection of electrical branches for example). They do not have any tuning pin. The energy distribution is then only defined by their internal description.

Accumulation elements (orange rectangular pictograms with an oblique bar) connect other elements, thanks to energy storage, which induces at least one state variable.

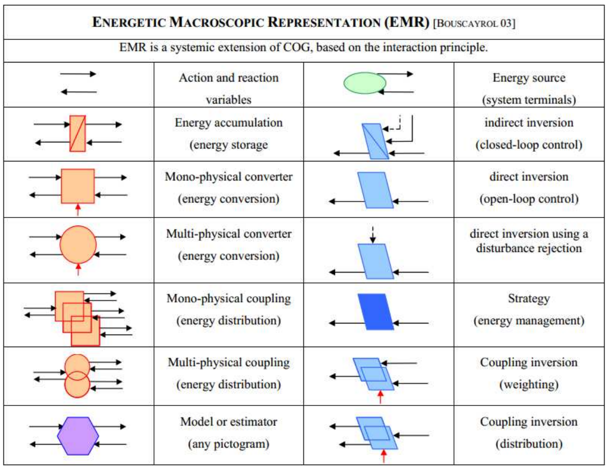
All these elements are connected through exchange vectors according to the principle of action and reaction. For energy conversion systems, specific association rules have been defined to build their EMR. The names of variables are associated with originating devices.

From the EMR of a system, one can deduce a control structure, which is composed of a maximum of control operations and measurements. This method is the so called **maximum control structure (MCS)**. Continuous lines are associated with the inversion of action variables while dotted lines are related to the rejection of disturbance variables. All control blocks are depicted by blue parallelograms because they handle only information.

A control structure has to inverse the global functions of the power system. In the MCS approach, the global control structure is decomposed into several control blocks. Each block has to inverse one power element of the EMR. Conversion elements are inverted directly. Accumulation elements need controllers in order to solve the inversion problem of their state variables. All the inputs of power elements, which are not used in the inversion chain, become disturbance inputs. So they are directly rejected in order to minimize their influence.

A tuning chain is defined from the technical requirements. It connects the chosen tuning input of the global system to the wished action output through action inputs of power elements. The other inputs therefore become disturbances. In most electric drive applications, the static converter is chosen as the tuning element.

Then a control chain is obtained by inversion of the tuning chain: from the reference variable to the tuning variable. All the variables are initially considered as measurable. So, the control chain links to control blocks, which are inversions of power elements connected by the tuning chain. It is obvious that the MCS is the most complete control strategy. In real cases, control structures can be deduced from the MCS by simplifications or by taking into account estimations of non-measurable variables. *Locment et al.* (Locment & Sechilariu 2010) developed an EVs charging system with photovoltaic grid-connected model using EMR which allows the EVs feeding at the same time as PV energy production. Then a corresponding Maximum Control Structure (MCS) is deduced from the EMR, through specific inversion rules: direct inversion (without controller) for items that do not vary over time, indirect inversion (with controller) for items that vary over time.



ENERGETIC MACROSCOPIC REPRESENTATION (EMR) [BOUSCAYROL 03]			
EMR is a systemic extension of COG, based on the interaction principle.			
	Action and reaction variables		Energy source (system terminals)
	Energy accumulation (energy storage)		indirect inversion (closed-loop control)
	Mono-physical converter (energy conversion)		direct inversion (open-loop control)
	Multi-physical converter (energy conversion)		direct inversion using a disturbance rejection
	Mono-physical coupling (energy distribution)		Strategy (energy management)
	Multi-physical coupling (energy distribution)		Coupling inversion (weighting)
	Model or estimator (any pictogram)		Coupling inversion (distribution)

Figure 5: EMR blocks introduction

3.2. Representation of HEVs

Chrenko et al. (Chrenko et al. 2007; Chrenko et al. 2008) use EMR to model fuel cell systems which includes its basic elements and its inversion, the Maximum Control Structure (MCS) in order to develop a fuel cell based auxiliary power unit capable of trigeneration (electricity, heat and refrigeration). She used the model based control development of fuel cell systems because often model based control approaches are rather focused on details of the system than on the overall system.

Allègre et al. (Allègre et al. 2013) realize a hybrid energy storage system (HESS) and flexible control scheme by using EMR. The HESS is composed by batteries and super-capacitors and four energy management strategies have been proposed to control the system. They compare 4 types of strategies because they want to evaluate the characteristics on different criteria: electric consumption, sizing and the lifetime of the batteries.

Martinez et al. (Solano Martinez et al. 2012) develop the different EMR control systems for a multiple architecture heavy duty hybrid vehicle and present different energetic configurations using the available power and energy sources. Their objective is to test the different energetic configurations using various power and energy sources: Fuel cell system, Super-capacitors, Flywheels and ICE. Therefore they chose to use EMR representation to design control structures.

Chen et al. use just one EMR model for different hybrid vehicle architectures (series, parallel and series-parallel). She used EMR to represent different components of the hybrid vehicle, and then switches the model to different architectures by changing the parameters' values. The main objective of this article is to provide a control strategy for an HEV using an Electric Variable Transmission (EVT). A simple deterministic rule based control strategy has been used and the final simulation results prove that EVT could not only satisfy the vehicle performance but also optimize ICE operation and fuel consumption is reduced compared to a conventional vehicle.

Lhomme et al. (Lhomme et al. 2008) build two EMR models to describe 2 states of a clutch, locked or slipping. Author chose to use EMR to represent the clutch working system because certain difficulties arise when attempting to model a clutch by traditional methods due to its nonlinear behavior. In the simulation, two models are used—one for the clutch slipping and another for the clutch locked. Both models are connected using a switch selector to respect the criteria that are necessary to ensure the physical energy flow that is required during the commutation between both models. And the simulation result shows that the switched causal modeling allows the clutch to be simulated without difficulty and with a relatively short computation time.

Liukkonen et al. (Liukkonen & Suomela 2012) design a method for an energy management scheme of a series hybrid powertrain which provides maximal use of the battery, ultra-capacitor, and fuel cell source. Authors describe an energy management algorithm for the dimensioning of the powertrain components.

Silva et al. (Silva et al. 2012) used EMR to model and control an electric vehicle because they want to use both functional (Bond graph model) and structural (EMR model) approaches in the same simulation environment in order to analyze the behavior of the vehicle and its control.

Asus et al. (Asus et al. 2014) used EMR to improve the energy management in a series hybrid race car using different control strategies.

3.3. Multi Architecture Simulation Approach

3.3.1 Modeling Approach

Goal is to provide a generic approach for a multi-architecture / multi-application modeling and control approach for hybrid vehicles. Therefore, the EMR-Model is divided into 2 parts which include the "Source of Vehicle" and the "Coupling Switch". "Source of Vehicle" includes the energy source sub-models and energy flow transmission as well as conversion sub models. The desired driving cycle data will be introduced in this part of the model with help of the reference command signals which are provided by “Coupling Switch”.

Figure 6 represents the EMR model structure of the “source of vehicle” which includes source of environment, chassis, wheel and transmission. This part does not change for different architectures. By changing the mass of vehicle, frontal surface, drag force coefficient, etc., it is possible to adapt the model to the type of vehicles simulated.

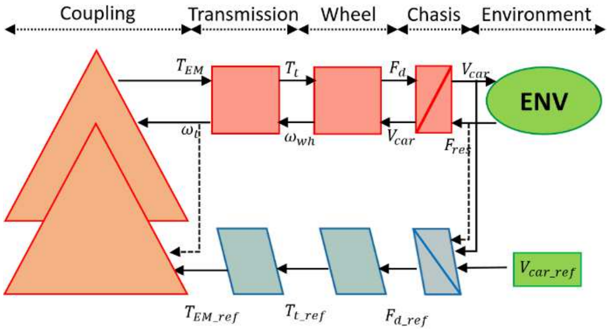


Figure 6: EMR of vehicle environment

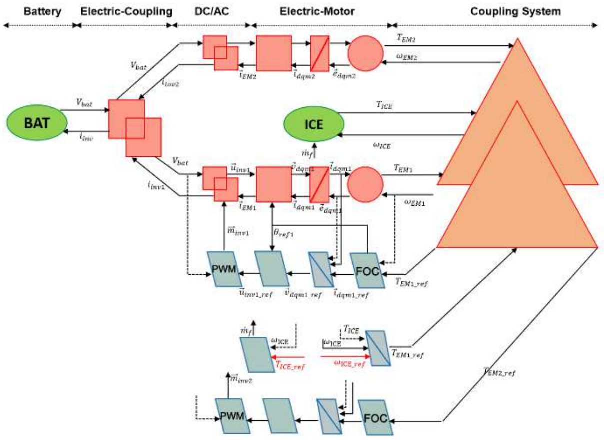


Figure 7: EMR of energy sources

Figure 7 represents the EMR model structure before torque coupling system, which includes the power sources: EM1, EM2, and ICE. The inputs of these power sources are rotational speed and their outputs are torque. They are controlled by their inversion based blocks. For different simulated vehicle, the power sources’ parameters as well as the engine fuel map and motor efficiency maps can be modified. For different architectures, not all of these power sources are needed. If the power source is not used in the selected architecture, its reference torque and rotational speed will be set to 0.

The coupling system plays an important role to describe different vehicle architectures.

For the series hybrid system, there is no connection between ICE and transmission, ICE is connected to EM2 (which works as generator). This generator only charges the battery. EM1 is the only propulsion element. Therefore the output torque of EM1 is connected directly to the transmission.

For the parallel hybrid system, EM2 will not be used and both ICE and EM1 drive the vehicle. Therefore, the torque is the sum of EM1 torque and ICE torque.

For the Series-parallel hybrid vehicle, there are 2 possible combinations: EVT and Planetary-gear-set. EM1 is connected to the transmission in order to drive vehicle. During braking, EM1 will work as a generator to recover the energy. ICE can help EM1 to drive the vehicle, or can be connected to EM2 to charge the battery.

3.3.2 System control

For the moment two different rule based control approaches have been used for the energy management.

For Series hybrid vehicle, the control strategy is realized by several lookup tables which are used to control the battery charging. The battery can be charged by regenerative braking or using the ICE based range extender.

For Parallel hybrid vehicle, the control strategy is realized using a state flow tool. Based on the inputs (battery SOC, required torque of vehicle and speed of transmission system) the output variables (torque split ratio between T_{ICE} and T_{req}) will be evaluated using 6 different modes based on SOC and T_{req}.

For Series Parallel hybrid architecture with planetary gear transmission, the control strategy is also realized by state flow as well. There are 4 working modes which include:

- mode0: Electric mode,
- mode1: E-CVT mode,
- mode2: Hybrid mode
- mode3: Regenerative braking mode.

During the braking, the wheel torque is split into two parts which include *regenerative electric braking* where the energy is used to recharge the batteries and *mechanic braking* where the energy is dissipated.

4. SIMULATION RESULTS

As presented before the availability of an easy to use global vehicle model is crucial for the development of the system control. Therefore a GUI (graphic user interface) has been developed which gives the possibility to choose between different vehicle types, different driving cycles and different hybrid architectures by simple clics. For the moment the approach developed by the authors provides the possibility to study 828 predefined combinations of cycle, vehicle and architecture are available. Moreover, it gives the possibility to start the simulation and represent the most important results graphically. Furthermore, it gives the possibility to adapt all parts of the vehicle individually. It is even possible to estimate the behavior of an internal combustion engine ICE that is especially designed for this case. Therefore the approach of *Asus et al.* (Asus et al. 2012). The user interface is presented in **Erreur ! Source du renvoi introuvable.**, which is developed by authors in order to facilitate the simulation for different vehicles in different driving cycles._The user interface consists of three parts, the left part is used to select the simulated vehicle, driving cycle and the hybrid structure, the middle part is used to display the vehicles and the parameters of their power system, the right part is used to plot the results, both 2d and 3d figures can be plotted. Furthermore, with the help of the other two cooperating GUIs, it is possible for the users to customize the driving cycle as well as engine parameters.

The most interesting reference point would be the behavior of a C-segment medium car like Toyota Prius for example.

Figure 9 presents the power split inside a C-segment medium series-parallel hybrid car on a motorway cycle. It can be seen, that the power needed by the car is a combination of the power delivered by the battery through the electric motor 1 (EM1). The internal combustion engine ICE is only used during start and around 300s. The fuel consumption on this cycle is equivalent to143g of gasoline fuel, which would be equivalent to 1.2L/100km.

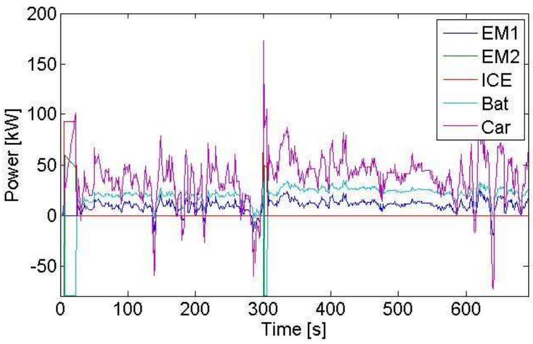


Figure 9: Power demand of C-segment medium car on motorway

A comparison of fuel consumption for different hybrid architectures of is presented in Table 1. It seems that the results for the same architecture and different driving cycles are comparable. However, the results for the different architectures have to be checked carefully. The low fuel consumption for series/parallel architecture can be described by the extensive use of the battery.

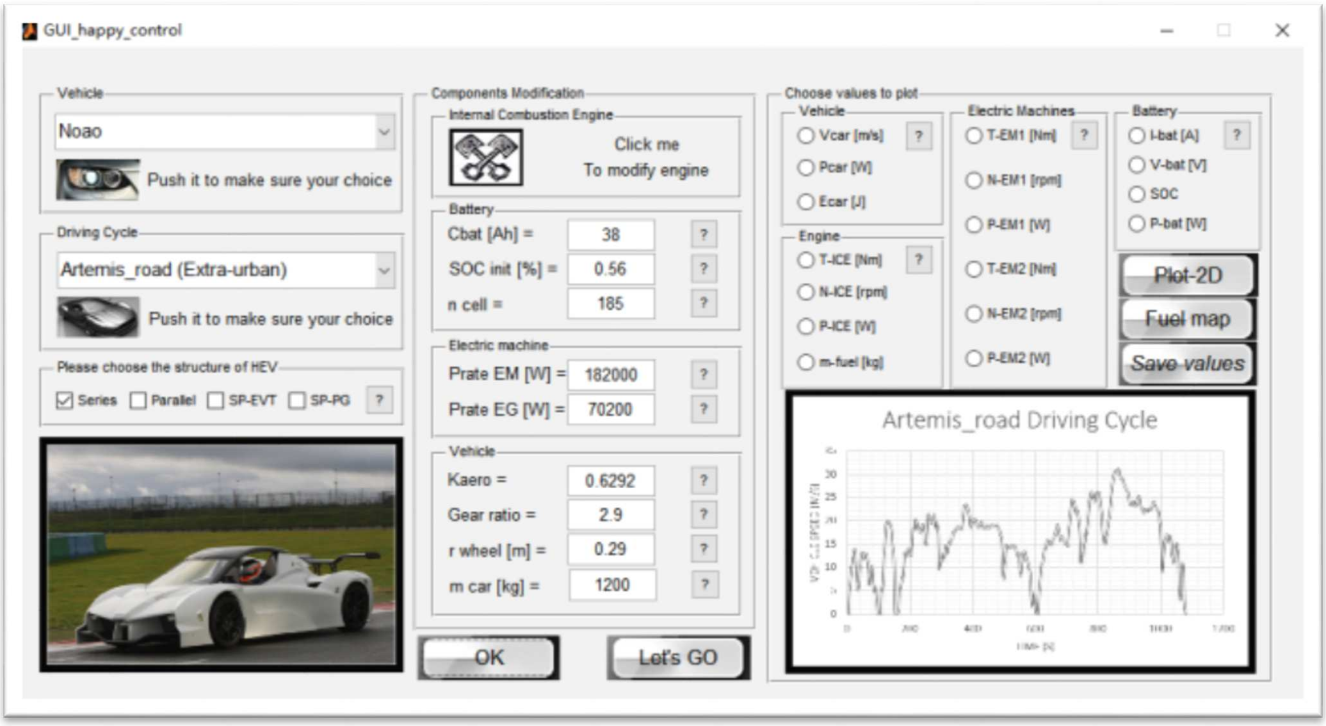
Table 1: Comparison of fuel consumption of C-segment middle class car in L/100km

	Urban	Extra-urban	Motorway
Series	2.95	5.35	6.43
Parallel	3.19	5.27	5.51
Series/Parallel	3.78	4.39	7.03

Furthermore, the model gives the possibility to compare the fuel consumption for different types of vehicles. **Erreur ! Référence non valide pour un signet.** presents the fuel consumptions of different series hybrid vehicles on different driving cycles. It can be seen that the fuel consumption increases from urban to extra urban driving cycle and from extra-urban to motorway driving cycle. This is understandable as the mean power demand increases with the driving cycles.

Table 2: Comparison of fuel consumption of different vehicles in L/100km

	Urban	Extra-urban	Motorway
Motorbike	0.93	2.29	4.51
Small Car (A-segment)	3.05	4.43	5.97
Medium Car (C-segment)	3.68	5.08	7.74
Bus	28.87	27.7	35.8



Vehicle: Noao

Driving Cycle: Artemis_road (Extra-urban)

Please choose the structure of HEV: ☑ Series ☐ Parallel ☐ SP-EVT ☐ SP-PG

Battery
Cbat [Ah] = 38
SOC init [%] = 0.56
n cell = 185

Electric machine
Prate EM [W] = 182000
Prate EG [W] = 70200

Vehicle
Kaero = 0.6292
Gear ratio = 2.9
r wheel [m] = 0.29
m car [kg] = 1200

Vehicle: ○ Vcar [m/s] ○ Pcar [W] ○ Ecar [J]

Engine: ○ T-ICE [Nm] ○ N-ICE [rpm] ○ P-ICE [W] ○ m-fuel [kg]

Electric Machines: ○ T-EM1 [Nm] ○ N-EM1 [rpm] ○ P-EM1 [W] ○ T-EM2 [Nm] ○ N-EM2 [rpm] ○ P-EM2 [W]

Battery: ○ I-bat [A] ○ V-bat [V] ○ SOC ○ P-bat [W]

Figure 8: Graphic User Interface (GUI)

5. CONCLUSIONS AND PERSPECTIVES

This work presents a unified multi-architecture / multi-application approach to simulate different hybrid vehicles using REM. Such a tool is required as nowadays several hybrid architectures exist in parallel and they are used for a multitude of vehicle applications from scooter, over vehicle, to busses. In order that the hybrid vehicle shows a real advantage with regard to conventional architectures, it is necessary to develop a well-adapted control. Therefore, it is interesting that EMR allows developing the control strategy by an inversion based approach. Different control strategies (rule based and optimization based) can be applied on hybrid vehicles.

In this example, a GUI was developed providing easy access to different hybrid architectures and control strategies. Different architectures of a middle class car are modeled using rule based control. Furthermore, different vehicle types like a scooter and a bus are modeled. Modeling results show coherent results and the capability of a single generic model to cover this multitude of applications.

In the following the approach will be checked carefully, different control strategies will be developed and results will be compared to real world data.

REFERENCES

Allègre, A.-L., Trigui, R. & Bouscayrol, A., 2013. Flexible real-time control of a hybrid energy storage system for electric vehicles. *IET Electrical Systems in Transportation*, 3(3), pp.79–85.

Amjad, S., Neelakrishnan, S. & Rudramoorthy, R., 2010. Review of design considerations and technological challenges for successful development and deployment of plug-in hybrid electric vehicles. *Renewable and Sustainable Energy Reviews*, 14(3), pp.1104–1110.

Asus, Z. et al., 2014. Model and Control Strategy Simulation of a Racing Series Hybrid Car. In *IEEE Vehicular Power and Propulsion Conference (VPPC)*. Combeira, Portugal.

Asus, Z. et al., 2013. Optimization of Racing Series Hybrid Electric Vehicle using Dynamic Programming. In *SESDE*. Athens, Greece.

Asus, Z. et al., 2012. Simple method of estimating consumption of internal combustion engine for hybrid application. *2012 IEEE Transportation Electrification Conference and Expo, ITEC 2012*.

Barrade, P. & Bouscayrol, A., 2011. Energetic Macroscopic Representation - An Energy-Flow Based Methodology dedicated for the control of multiphysics systems.

Chen, K., Bouscayrol, A., Berthon, A., et al., 2009. Global modeling of different vehicles. , (June), pp.80–89.

Chen, K., Bouscayrol, A., Delarue, P., et al., 2009. Simulation of an Unified Control Scheme for Different Hybrid Electric Vehicles. , pp.3842–3847.

Cheng, Y. et al., 2009. Global Modeling And Control Strategy Simulation. , (June), pp.73–79.

Chrenko, D. et al., 2015. Novel Classification of Control Strategies for Hybrid Electric Vehicles.

Chrenko, D., Pera, M.-C. & Hissel, D., 2008. Inversion based control of a diesel fed low temperature fuel cell system. *2008 13th International Power Electronics and Motion Control Conference*, pp.2156–2163. Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=4635585.

Chrenko, D., Péra, M.-C. & Hissel, D., 2007. Fuel Cell System Modeling and Control with Energetic Macroscopic Representation. In *IEEE ISIE*. Vigo, Spain.

Guzzella, L. & Sciarretta, A., 2010. *Vehicle Propulsion Systems - Introduction to Modeling and Optimization*, Springer.

Ifak, S.N. & Iml, H.V., 2015. Models and Methods for the Evaluation and the Optimal Application of Battery Charging and Switching Technologies for Electric Busses. , (Iml).

Kutter, S. & Bäker, B., 2010. Predictive online control for hybrids: Resolving the conflict between global optimality, robustness and real-time capability. In *IEEE Vehicle Power and Propulsion Conference*. IEEEXplore, pp. 1–7.

Lhomme, W. et al., 2008. Switched Causal Modeling of Transmission With Clutch in Hybrid Electric Vehicles. *IEEE Transactions on Vehicular Technology*, 57(4), pp.2081–2088. Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=4383362.

Lhomme, W., Bouscayrol, a. & Barrade, P., 2004. Simulation of a series hybrid electric vehicle based on energetic macroscopic representation. *2004 IEEE International Symposium on Industrial Electronics*, (May), pp.1525–1530 vol. 2. Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=1572040.

Liukkonen, M. & Suomela, J., 2012. Design of an energy management scheme for a series-hybrid powertrain. *2012 IEEE Transportation Electrification Conference and Expo (ITEC)*, pp.1–6. Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=6243507.

Locment, F. & Sechilariu, M., 2010. Energetic Macroscopic Representation and Maximum Control Structure of electric vehicles charging photovoltaic system. *2010 IEEE Vehicle Power and Propulsion Conference*, pp.1–6.

Le Mans, 2012. Règlement Technique pour Prototype 2012 2012 Technical Regulations for Prototype.

Marc, N. et al., 2010. Sizing and fuel consumption evaluation methodology for hybrid light duty vehicles. In *25th World Battery, Hybrid and Fuel Cell Electric Symposium and Exhibition (EVS).*

Shenzhen, China.

Prechelt, L., V-Modell XT. , pp.1–38.

Silva, L.I., Bouscayrol, a. & De Angelo, C.H., 2012. Modeling and control of an electric vehicle combining bond graph and Energetic Macroscopic Representation. *2012 IEEE Vehicle Power and Propulsion Conference*, (4), pp.973–977. Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=6422769.

Solano Mart'\inez, J. et al., 2012. A survey-based type-2 fuzzy logic system for energy management in hybrid electrical vehicles. *Information Sciences*, 190, pp.192–207.

Tie, S.F. & Tan, C.W., 2013. A review of energy sources and energy management system in electric vehicles. *Renewable and Sustainable Energy Reviews*, 20, pp.82–102. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1364032112006910.

Tingting, D., 2011. Design Method and Control Optimization of an Extended Range Electric Vehicle. , 15(1).

Wikipedia, Volvo B5LH.

Zhang, P., Yan, F. & Du, C., 2015. A comprehensive analysis of energy management strategies for hybrid electric vehicles based on bibliometrics. *Renewable and Sustainable Energy Reviews*, 48(205), pp.88–104. Available at: http://dx.doi.org/10.1016/j.rser.2015.03.093.