**Call for a PhD Position:** New energy-efficient control strategy for Hybrid and Electric Vehicles - battery management and predictive optimization

**Context:**

Land vehicles such as motorcycles, cars, buses, trucks and tractors normally use internal combustion engine to propel their movements thus using fossil fuel as an energy source. Fossil fuels account for 85% of energy sources because it is still considered as the least expensive source of energy in a manner of exploitation and cost of application as compared to other types of energy manipulation [1]. But recently, the price of crude oil has become more and more expensive and industries have started exploring alternatives to replace or reduce their dependence on this source. In the sector of transport, people especially researchers are obligated to build electric vehicle (EV) and develop the hybrid electric vehicle (HEV) propulsion system which use two or more types of energy to drive a vehicle. In addition, regulations on pollution and emission of greenhouse gases have become stringent in most countries in order to diminish global warming effects.

Even though the EVs driving range and initial cost is very high, it offers advantages like high energy efficiency, permit diversification of energy resources, allow load equalization of power systems, zero local and global emissions and reduce noise pollution [2]. However, EV has some drawbacks in its capacity to operate over long distances and recharging properties, which make HEV a breakthrough to eliminate these disadvantages. Other than the HEV inconvenience of eliminating the zero emission concepts and having the added complexity, we can conclude that the promising perspective in development of EV and HEV make these systems as the most feasible solution for our future transportation.

**Literature review on control strategy for HEV:**

A hybrid propulsion system is composed of different types of engines and power converters [3]. Generally, it comprises of an internal combustion engine (ICE) or a fuel cell (FC), an electric motor (EM) or a generator (G), and a battery [4]. The most widely built drive train architectures are series, parallel, combination (power split) and complex hybrid. Along with this development of multiple energy source and architecture is the challenge to manage the power flow control for both mechanical and electrical paths, with the additional objective of reducing polluting emissions, decreasing fuel consumption and increasing energy efficiency.

Hybrid vehicles hold many interesting benefits related to the small size of an ICE which proposes design on average power demand and not on peak power demand [5]. Moreover, we can control it to work on its highest efficiency point and establish lower fuel consumption. Since a generator is used in some configuration, we can generate greater torque at low speed and variable speeds with less torque in some of the systems in contrast to a system with an ICE only. Furthermore, HEV embrace the possibility of installing the regenerative braking system to recapture partially kinetic energy to recharge the battery and lessen wear on the brakes [6]. Consequently, HEV need intensive study to compromise above gains with the vehicle weight and structure complexity as well as the control strategies.

An ICE torque is tuned by an engine control unit (ECU), engendered by the amount of fuel injected into the cylinders [3] and its speed is determined by the instantaneous gear ratio and the vehicle speed. Numerous approaches have been taken and applied as control strategies of HEV classified in two approaches: (i) Rules-based strategy and (ii) Optimization-based strategy. In rules-based strategy, we can find two methods, a deterministic rules-based method and a fuzzy rule based method [7]. A deterministic rules - based method is based on the analysis of hybrid powertrain power flow, an ICE fuel and emission map, and human experience to decide partition of power between power converters, commonly implemented via lookup table. This method consists of thermostat on-off strategy [8], power follower control strategy, modified power follower strategy and state machine- based strategy [9]. A fuzzy rules - based method is seen as the most logical approach of multidomain of hybrid powertrain, nonlinear and time varying plant [10]. This method is well known for its robustness and adaptability. It comprises of conventional fuzzy strategy, fuzzy adaptive strategy [11], and fuzzy predictive strategy.

The other acknowledged control strategy is the optimization-based control strategy which also comprises of two classifications, i.e. a global optimization and a real time optimization. The global optimization intends on minimizing the total energy losses throughout a cycle [12]. Several solutions are proposed in achieving target of performance assemble from a cost function compliant to an optimal global operating point over a cycle, for example linear programming, simulated annealing, control theory approach, dynamic programming (DP), stochastic DP, game theory, genetic algorithm (GA), artificial neural network algorithm (ANN) [13] and direct rectangle (DIRECT) algorithm [14]. A real time optimization has an instantaneous optimization cost function for fuel consumption and takes into account variation of energy stored in a battery [10]. A high-performance detection device is needed to give instantaneous information from each measured parameter. There are a number of strategies incorporated within this base, for instance, equivalent fuel consumption [15], decoupling control, robust control approach and optimal predictive control.

Nowadays, the improvement of hybrid vehicle technology is growing in a grand pace, thanks to well develop computer simulation and powerful software that can represent models of vehicle components as well as behaviors mathematically and scientifically. Thus, researchers can do experiments virtually, rapidly, and less time and cost consuming before they execute it on the real physical equipment and gain results.

**Problem Statement:**

The modeling of control strategy for HEV is generally based on a specifically imposed driving cycle, thus resulting in unyielding design parameters of control for a particular case. At this day and age, automobile buyers demand a lot of requirements in selecting a reliable HEV. While at the same time car manufacturers need to broaden their objectives on building HEVs and discovering new ideas. Accordingly, there is still a vast space in development of control algorithm that we can explore and exploit in such system of HEV. The general aim of this PhD is to develop new potential possible control strategy models and integrate them with HEV architecture taking into account the two main factors:

- the impact of the control strategy on the thermoelectric behavior of the battery used for propulsion and on all auxiliaries,
- the impact of the environment/infrastructure information (driver profile, road topology, weather conditions, traffic light status, etc.) for a better predictive energy optimization,

**PhD planning and environment:**

The main objective of this PhD is to develop a new control strategy and viable optimization method to be planted in a system of hybrid electric vehicle (HEV). A development of a virtual model for simulation will represent precisely the characteristics of all HEV components. The model should be practicable to be manipulated so that it can be used with different objectives of control strategies and optimization methods to fit the HEV configurations. The best strategy and optimization method from simulation will be chosen and verification from experiment will be made before the final algorithm is proposed and developed for future HEV design. The final objective is to develop a simulator that will allow to visualize and simulate the different vehicle parameters such as the instantaneous torque, the energy quantities exchanged by the power electronics as well as the thermo-electrical behavior of the power pack.

Hence, the schedule of research work for this PhD is as follows:

- Step 1 - State of art on the related works dealing with HEV, battery management (thermoelectric behavior) and optimization models (4-5 months).
- Step 2 - Impact of the control strategy on the HV battery and auxiliaries: The objective of this part is to develop models of control strategies to manage efficiently the HV battery and its auxiliaries. The deliverable is a vehicle simulator for electrical application. The study will focus on : modelling the essential physical parameters of vehicles, determine the power required according to the rolling profiles, develop a control strategy model to optimize energies, experimental testing on the "electric traction chain" test bench and develop a simulator that can predict the energy consumption of vehicles according to different parameters (12-15 months).
- Step 3 - Predictive energy optimization using environment/infrastructure information: In the context of the electric car, efficient management of the energy is essential. The objective of this part is to develop predictive models of battery energy consumption based on the collected environment/infrastructure information (driver profile, road topology, weather conditions, traffic light status, etc.) (12-15 months).
- Step 4: Writing of the thesis and preparation of the PhD defense (6 month).

Many excellent international journals and conferences that cover this area will be the subject of our publications, we cite for the international journals: IEEE Journal of Emerging and Selected Topics in Power Electronics, IEEE Transactions on Power Systems, Computer and Electrical Engineering Journal, Sustainable Cities and Society.

This thesis will be located at SERMA (PESSAC), in cooperation with University of Burgundy (ISAT/DRIVE Nevers).

At SERMA, the PhD student will join the team Energy engineering. She / he will be under the supervision of Peter Herssens and the all R&D team of SERMA Group.

At DRIVE Lab, the PhD student will join the team EMIE (Energy, Mobility, Intelligence and Environnement) having an expertise on electric and hybrid vehicles, energy efficiency and connected vehicles. She / he will be under the supervision of Dr. E. Aglzim and Pr. SM. Senouci.

**Contacts:**
Industrial supervisor: Peter Herssens, SERMA Energy, Pessac,
Academic supervisors: Pr. Sidi Mohammed Senouci and Dr. El-hassane Aglzim, University of Burgundy, Nevers.

**Expected starting date:** October/November 2020.

**Expected Profile:**
Candidates should own a Master (M.Sc.) or Engineer (B.Sc.) degree with strong skills in computer science, electronics/electrical engineering, mathematics and optimization methods. Practical programming skills and software tools (e. g. Matlab / C and C++) and fluent English (written and spoken) are required. Above all, the applicants must be motivated to learn quickly and work effectively on challenging research problems.

**How to Apply:**
Application process (deadline June 2020)
The following documents are required:
- CV,
- motivation letter,
- statement of research experience and interests,
- transcripts of University transcripts and
- (at least) two reference letters

as attachments of an email, whose subject will be "Application for PhD position at SERMA", which must be addressed to Peter Herssens (p.herssens@serma.com), El-hassane Aglzim (el-hassane.aglzim@u-bourgogne.fr) and Sidi Mohammed Senouci (sidi-mohammed.senouci@u-bourgogne.fr).
Web links of research articles authored by the applicant or the internship report are welcome to be included, too.

## References

[1] **Willem P. Nel and Christopher J. Cooper**, *"Implications of Fossil Fuel Constraints on Economic Growth and Global Warming"*, Energy Policy 37, Elsevier, Johannesburg South Africa, 2009.

[2] **K.T. Chau and Y.S. Wong**, "*Overview of Power Management in Hybrid Electric Vehicles"*, Energy Conversion and Management, vol. 43, Pergamon, Hong Kong, 2002.

[3] **Farzad Rajaei Salmasi**, "*Control Strategies for Hybrid Electric Vehicles: Evolution, Classification, Comparison, and Future Trends"*, IEEE Transactions on Vehicular Technology, vol. 56, September 2007.

[4] **P. Caratozzolo, M. Serra, and J. Riera**, "*Energy Management Strategies for Hybrid Electric Vehicles"*, IEEE, Spain, 2003.

[5] **Omonowo D. Momoh and Michael O. Omoigui**, "*An Overview of Hybrid Electric Vehicle Technology"*, IEEE, Texas USA, 2009.

[6] **Yimin Gao, Liang Chu, And Mehrdad Ehsani, IEEE Fellow**, "*Design and Control Principles of Hybrid Braking*

*System for EV, HEV and FCV"*, IEEE, 2007.

[7] **Kamil Cagatay Bayindir, Mehmet Ali Gozukucuk, Ahmet Teke**, "*A Comprehensive Overview of Hybrid Electric Vehicle: Powertrain Configurations, Powertrain Control Techniques and Electronic Control Units"*, Elsevier, Turkey, 2011.

[8] **Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi**, "*Modern Electric, Hybrid Electric, and Fuel Cell Vehicles Fundamentals; Theory, and Design"*, CRC Press, USA, 2004.

[9] **Weimin Li, Quoqing Xu, Zhancheng Wang and Yangsheng Xu**, "*A Hybrid Controller Design for Parallel Hybrid Electric Vehicle"*, IEEE International Conference on Integration Technology, Shenzhen China, 2007.

[10] **Sanjaka G. Wirasingha and Ali Emadi**, "*Classification and Review of Control Strategies for Plug-In Hybrid Electric Vehicles"*, IEEE Transactions on Vehicular Technology, vol. 60, January 2011.

[11] **Amir Poursamad and Morteza Montazeri**, "*Design of Genetic-Fuzzy Control Strategy for Parallel Hybrid Electric Vehicles"*, Control Engineering Practice 16, Elsevier, Tehran Iran, 2008.

[12] **Lipeng Zhang, Cheng Lin, and Xiang Niu**, "*Optimization of Control Strategy for Plug-In Hybrid Electric Vehicle Based on Differential Evolution Algorithm"*, IEEE, Beijing China, 2007.

[13] **Qiuming Gong, Yaoyu Li, and Zhongren Peng**, *"Power Management of Plug-In Hybrid Electric Vehicles Using Neural Network Based Trip Modeling",* IEEE 2009 American Control Conference, USA, June 2009.

[14] **Yaming Zhang, Fengchun Sun, Hongwan He**, "*Control Strategy Optimization for Hybrid Electric Vehicle Based on DIRECT Algorithm"*, IEEE VPPC, Beijing China, 2008.

[15] **Lino Guzzella and Antonio Sciarretta**, "*Vehicle Propulsion Systems; Introduction to Modeling and Optimization"*, Chapter 7, Springer, Switzerland, 2007.