Electrical Vehicle Engineering master degree for new developments in automotive industry

E. Semail[1,2], A. Bouscayrol[2,3], Z. Moumni[4], P. Rivière[5], E. Fortin[6]
(1) Arts et Metiers PARISTECH, L2EP, Lille, France
(2) Univ Lille Nord de France, L2EP, Lille, France
(3) MEGEVH, French network on HEVs, France
(4) ENSTA PARISTECH, France
(5) Mines PARISTECH, France
(6) Ponts PARISTECH, France
eric.semail@ensam.eu

***Abstract*- Four French Grandes Écoles (Engineering and Business Schools) of PARISTECH open in October 2010 an education program which main objective is the impact study of the massive insertion of electrical energy in autonomous vehicles. The program with a common core curriculum and two different options is described..**

I. INTRODUCTION

Your The development of "green cars" is of growing interest in automotive industry [1][2]. For example, Renault French Car maker is leading the industry in developing innovative partnerships with governments and energy players around the world to promote electric vehicles. Renault has planned to launch in the first-half of 2011 electric vehicles in Israel and Denmark, and then in the rest of Europe [3]. Due to the future large-scale production of electric vehicles, it appears to Renault important needs for a specific training in this new application field. Several months of discussions with French Grandes Écoles (Engineering and Business Schools) of PARISTECH lead to a program supported by four schools: Arts et Metiers Paristech, ENSTA Paristech, Mines Paristech and Ponts Paristech. The program is not focused only on electrical technology but also on the several impacts of its use for autonomous vehicles. As energy density of electrical storage is far from energy density of petroleum, the introduction of electrical energy in autonomous vehicle will imply new organization in the energy distribution network: technical and social impacts of this mutation will be studied. Similarly, the architecture of an electric car must also take in account new constraints linked to the use of electric storages and motors: thermal, mechanical and security aspects must be reconsidered.

In electrical engineering education, there is already strong collaboration between industry and universities, specifically for drive applications [4][7]. Some recent experiences have been developed for EVs and HEVs, but more transversal and interdisciplinary approaches are required [8]. This program is also supported by MEGEVH, the French scientific network on HEVs **Erreur ! Source du renvoi introuvable.**, and will benefits of the last scientific and technological development in the field.

The program described in next sections is thus split into one common core curriculum and two options chair.

II. COMMON CORE CURRICULUM

All students will follow the common core curriculum. In this core, a large part will be devoted to the impacts on human organization and habits that the use of electrical vehicles in a sustainable context will induce. Solutions using Information and Communication Technologies (ICT) in order to smooth the transformations in human habits are introduced: security feeling by virtual increase of energetic autonomy; simulation of usual thermal engine behavior, etc… Main concepts on new methods for sustainable design and optimized consumption of energy are presented.

More generally, the objectives of the common core are:

- To expound the new technological and social networks that will be induced by the use of electrical energy in autonomous vehicle ;
- to practise on generic examples tools and methods which allow the analyze and development of new structures for autonomous vehicles. Two kinds of new structures are considered:
  - **functional:** vehicles must use the high flexibility in control of the electrical energy for optimal energy management ;
  - **architectural:** structures must be adapted in order to maintain security

The different units are given in Table I.

TABLE I

Unit title	Acronym	Hours
Issues of sustainable mobility	M1	30
State of arts : electricity in classical thermal vehicle	M2	30
Impact of electrical vehicle on electrical grids	M3	20
Sustainable Design	M4	30

978-1-4244-8218-4/10/$26.00 ©2010 IEEE

Life cycle and materials	M5	20
Benefits of ICT (Information Communication Technologies)	M6	30
Electrical Energetic components in traction	M7	30
Analyze of energetic flux in hybrid and electric vehicles	M8	30
Energetic design and optimization by software engineering	M9	30

III. ELECTRICAL ENGINEERING OPTION

The main objective is to bring to the student the knowledge, in electrical engineering field, of the technological solutions currently and soon available. Focus is done on electrical means in the management and storage of energy in hybrid or pure electrical vehicles from the electrical grid up to the wheels.
There are four units in this option given in Table II

TABLE II

Unit title	Acronym	Hours
Electro-Mechanical Conversion	L1	70
Electrical Modulation by Electronic Power Converter	L2	60
Energy storage	L3	50
System Control by project approach	L4	90

A. Electro-Mechanical Conversion unit

Motivation and objectives: to give necessary knowledge to allow understanding physical and technological constraints on electrical machines. The student will be able to achieve choice of machine under energetic constraints (instantaneous or average efficiency) but also environmental (temperature, space, sustainability) and fault tolerance constraints. Manufacturing processes on electrical machines and constraints on large scale processes will be given.

- Magnetic, insulating materials :
  Key words : saturation, demagnetization , losses ;
- Electrical Machine structures : comparison of classical and special automotive electromechanical conversion using various criterion;
  Key words : torque density ; volume density; efficiency, cost ;
- Permanent magnet synchronous machines;
  Key words : structural advantages/drawbacks ; axial/radial flux machines; constant power mode; wheel motor
- Elements of Design and associated tools ;
  Key words: thermal constraints, mechanical constraints, noise, Finite Element tool;
- Elements on manufacturing and production constraints

B. Electrical Modulation by Electronic Power Converter unit

Motivation and objectives: Adaptation of electrical energy between sources and loads implies to consider simultaneously constraints on embedded systems and also functionality, efficiency and electromagnetic compatibility in the choice of electronic power converter. The student will be able to achieve choice of electronic power converters;

Key words : voltage level adaptation; efficiency, reliability/fault tolerance, compatibility ;

- Power devices : active components (semi-conductors component and associated drivers; passive component (capacitors/ windings), characteristics and factor of evolution; estimation of losses ;
- Adaptation of on-board voltage levels (DC/DC conversion); battery and super-capacitor recharge;
- Electromagnetic compatibility : physical phenomena, norms and solutions (shielding, active and/or passive filtering)
- Control techniques of Voltage Source Inverters : Comparisons from Pulse Amplitude Modulation up to Flat-Top Pulse Width Modulation ;

C. Energy storage unit

Motivation and objectives: the low electric density storage in comparison with petroleum one implies a better management of energy. This unit allows supplementing general knowledge given in M7 unit. The student will be able to define requested electrical energy storage from payload with constraint on capacity and power:

- Caracterization and modeling of different batteries and /or super-capacitors;
- Cycling capability (charge/discharge) ;
- Balancing and monitoring of charge by electronic circuits;
- Caracterization and modeling of flywheels ;

D. System Control unit

Motivation and objectives: electric or hybrid vehicle is a system with a substantial control part. The student will be able to achieve the control of the energetic conversion chain. As the system has components studied in the three other units of the option, the main part of the unit will be organized as a project unit using a systemic structural approach denoted Energetic Macroscopic Representation.
Key words : simulation; feedback and forward control, energetic modeling ;

IV. VEHICLE ARCHITECTURE OPTION

The main objective is to examine the impact of electrical energy on classical professions of automotive. Design methods are revised in mechanical, mechatronic, acoustic and material fields. Considering the increase of mass for energy storage, focus is done on the necessity to reduce inactive masses keeping a high level of security. Methods for crashworthiness design are revisited.

TABLE III

Unit title	Acronym	Hours
Engineering of mechanical systems applied to electrical vehicle	P1	100
Engineering of electrical systems applied to electrical vehicle	P2	90
Machine-Human Interface / Couplings between mechanical and electrical systems	P3	80

A. Engineering of mechanical systems applied to electrical vehicle unit

This unit contains three sub-units:

- **Design and Simulation with CAD softwares**
  Motivation and objectives: ability to use simulation tools for discrete and continuous systems in transient and steady-state operations.
  Numerous computer softwares such as CATIA, ADAMS and MATLAB will be used at first for studying patented systems. Inductive approach will be used: after use on academic systems, student will practice in a personal project which combines the different computer softwares.
  Key words : co-simulation, dynamic simulation
- **Numerical modeling using Finite Element Method : application to Electrical Vehicle**
  Motivation and objectives: ability to use softwares based on Finite Element Method taking into account new mechanical constraints such as batteries, electrical motor and power converter. Specially for the design of crashworthiness.
  Key words : Calculation of structure, Finite Element Method, Crash
- **Acoustics of vehicle**
  Motivation and objectives: with the disappearance of thermal engine, noise in electrical vehicle must be reconsidered. Noise from tires, electrical motor, and power converters has to be taken into consideration more accurately. Global approach will be described with combined measurements, analytical modeling and simulation in order to define adapted mechanical structure of the vehicle.
  Key words : psychoacoustics, aeroacoustics, acoustic comfort.

B. Engineering of electrical systems applied to electrical vehicle unit

This unit contains four sub-units:

- **Automatic and Control of System**
  Motivation and objectives: give a large vision of the techniques of automatic as applied in industry and particularly in the case of hybrid vehicles
  Key words: command laws, stability, trajectory optimization.
- **Computer software of vehicle and embedded systems**
  Motivation and objectives: give to the students a comprehensive approach of the embedded systems as well as the programmable electronics. These elements are necessary for the energy optimization.
  Key words : embedded systems, logic of control.
- **Security and reliability of electrical vehicle**
  Motivation and objectives: explain how one must apprehend security and issues reliability associated with the electric vehicles design.
  Key words : security, reliability, robustness
- **Battery storage**
  Motivation and objectives: the student will acquire the main knowledge about the actual techniques associated with battery storage as well as the coming ones.
  Key words : energy storage, battery, technological aspects, battery of the future.

C. Machine-Human Interface / Couplings between mechanical and electrical systems unit

This unit contains four sub-units:

- **Modeling of mechanical, thermal and electromagentic couplings**
  Motivation and objectives: use the finite elements method to simulate the electromechanical systems by taking into account electromagnet-thermo-mechanical coupling.
  Key words : finite elements, electromechanical coupling.
- **Mechatronics**
  Motivation and objectives: present a panorama of mechanical as well as electronic components and the interaction between them in the context of electric vehicles.
  Key words : mechatronics, mechanical components, electrical components.
- **Human factor**
  Motivation and objectives: give to the student a comprehensive approach to model the interaction between the vehicle and the persons.
- **Smart materials**
  Motivation and objectives: present the static as well dynamic performance of smart materials. Attention will be paid to the potential use of these multifunction materials in the context of electric vehicles.
  Key words : active materials, piezoelectric materials, active polymers, magnetic materials, shape memory alloys.

ACKNOWLEDGMENT

Acknowledgment for support of Renault French Car maker.

REFERENCES

[1] G. Eason, B. Noble, and I.N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” *Phil. Trans. Roy. Soc. London*, vol. A247, pp. 529-551, April 1955.

[1] C.C. Chan, Y. S. Wong, A. Bouscayrol, K. Chen, "Powering Sustainable Mobility: Roadmaps of Electric, Hybrid and Fuel Cell Vehicles", Proceedings of the IEEE, vol. 97, no. 4, April 2009, pp. 603-607.

[2] P. Fairley, "Speed bumps ahead for electric-vehicle charging", IEEE spectrum, Vol. 47, no. 1, pp. 13 – 14, January 2010.

[3] J. Perrin, "Zeo-Emission Vehicles and Renault policy", CPA Expo Conf, Toulouse, October 2009.

[4] F. Blaabjerg, M. Kazmierkowski, J. Pedersen, P. Thorgersen, M. Tonnes, "An industry/university collaboration in power electronics and drives", *IEEE ton Education*, vol. 43, no. 1, February 2000, pp. 52-57.

[5] P. Buechner, "New facilities for teaching and research with decentralised electric drive systems", *EPE'05*, Dresden (Germany), September 2005.

[6] A. Bouscayrol, A. Bruyère, P. Delarue, F. Giraud, B. Lemaire-Semail, Y. Le Menach, W. Lhomme, F. Locment, "Teaching drive control using Energetic Macroscopic Representation - initiation level", *EPE'07*, Aalborg (Denmark), September 2007

[7] P. Gambôa & all, "Modern Technologies for Experimental Education in Industrial Electronics and Electric Drives", *EPE'05*, Dresden, (Germany), September 2005.

[8] A. Emadi, T. M. Jacobinus, "Interprofessional projects in advanced automotive power systems: an integrated education and research multidisciplinary approach*", IEEE Transactions on Education*, Vol.: 47 , no: 3, pp. 356 – 360;

[9] MEGEVH, French scientific network on HEVs (http://l2ep.univ-lille1.fr/megevh/)