**PhD in Energetics**

**Research Title:** Hybrid Powertrain Design and Control based on Artificial Intelligence solutions: Deterministic/Stochastic Type Optimizers and Machine-Learning Techniques

**Funded by**

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**Context of the research activity**

In the recent years, the automotive industry has dedicated a great deal of effort to developing innovative technologies for the realization of green vehicles characterized by low CO2 and pollutant emissions. Powertrain electrification is bound to play a significant role to achieve such purpose. Electrified vehicles include FEVs (Full Electric Vehicles) and (P)HEVs, i.e. (Plug-In)Hybrid Electric Vehicles. FEVs offer a way to reduce the oil dependency of road transport, diminish urban air pollution and combat climate change (if electricity is produced from low-carbon sources). However, the main road-blocks that negatively affect customer acceptance are:

- high costs, mainly related to the batteries.
- compromises on performance and range limitations
- re-charging time

(P)HEVs offer improved fuel economy and lower emissions than conventional vehicles (CVs), as well as the possibility of increasing the driving range and of taking advantage of
existing fuel infrastructures with respect to FEVs. However, the exploitation of the full potential of (P)HEVs requires dedicated energy management systems capable of controlling each power-unit. Moreover, the economic convenience of (P)HEVs is strictly dependent on the driving mission specification.

In the framework of a joint research project with FPT Industrial, a toolbox has been developed in order to identify the best powertrain layout for a (P)HEV in terms of costs, energy consumption, GHG and/or pollutant emissions. A dedicated optimization of the initial vehicle design (component sizing and weight) and the contemporary optimization of the operating strategy of ICE, EMS and battery SOC is carried out by the tool. Vehicle performance targets (max velocity, acceleration, grade, payload, ...) are added as constraints to the optimization process. After Treatment System thermal management is also taken into account.

Main outcomes of the toolbox are:

- Optimal design configuration: hybrid concept and size of powertrain components (ICE, EMs, battery, transmission and gear ratios, final drive ratios, ...)
- OEM/operation cost of the optimal solution
- Mission trajectories and control strategy trajectories for optimal and non-optimal time histories of torque/speed of ICE and Electric Machines (EMs) along the driving missions
- Relations between operating costs, product costs, TCO, CO2 emissions, fuel consumptions, etc. for different design configurations
- Critical analysis of how ICE and related accessories should be modified/managed to better suit the new operating conditions in the hybrid architecture

As already highlighted, a dedicated energy management strategy is of paramount importance, especially for PHEVs. A new approach for the identification of the vehicle on-board control strategy will be developed and applied, stemming from the unsupervised machine learning technique developed in in SAE 2016-01-1243

| Objectives | OBJ1: Estimate the impact of the vehicle driving mission on the performance of the commercial vehicles, including effects from main environmental conditions that might affect the vehicle performance due to the auxiliary systems |
The aim of this analysis is to understand the usability of the different vehicle solutions

**OBJ2**: Enhance toolbox prediction of engine-out ICE emission levels (NOx and soot), based on modelling approaches and deep-learning techniques developed and applied in other research projects (such as IMPERIUM IA H2020: [http://www.imperium-project.eu/](http://www.imperium-project.eu/))

**OBJ3**: Develop model-based approach for thermal transient simulation of ICEs and integrate them in the toolbox.

**OBJ4**: Develop and apply AI techniques for the identification of the vehicle on-board control strategy by means of machine-learning and reinforcement learning solutions. Machine-learning will be based on the optimal control trajectories identified by toolbox benchmark optimizers over a wide range of driving scenarios whereas reinforcement learning will identify rules so as to determine optimal control solutions. A trade-off will be attained with respect to an adaptive optimization of the control strategy that allows for a more comprehensive understanding of the mission (eHorizon, mission-based learning).

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Skills and competencies for the development of the activity

- Technical competences about: ICE operation and modelling; HEV architecture and modelling; optimization techniques; machine-learning techniques.
- Good knowledge of programming and simulation tools (Matlab, Simulink) and commercial codes for ICE simulation (such as GT-Power, AVL boost, Ricardo Wave, ...).
- Capability to work in a multidisciplinary research team
- Good knowledge of the English language