DIPARTIMENTO DI INGEGNERIA
CORSO DI DOTTORATO IN INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE -
PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING - 36TH CYCLE

Title of the research activity:	Development and optimization of a hybrid powertrain with multiple energy recovery systems
State of the art:	The worldwide transportation scenario for the next decades is strongly influenced by the spread electric motors, due to the increase in energy storage efficiency, and by the need to reduce the enormous anthropic effect on both large scale (climate change) and small scale (local pollutant emissions) [1]. As for internal combustion engines, more and more severe regulations require an improvement in fuel economy, ultimately resulting in a reduction of carbon dioxide emission, and a reduction of tailpipe emissions (carbon monoxide, unburnt hydrocarbons, particulates and nitrogen oxides [2]). The transition to a type of economy completely independent of fossil fuels is not immediately possible; therefore, a phase of gradual transition from internal combustion engines to the large-scale use of electric motors and the exploitation of renewable energy sources is necessary. In this context, hybridization is a promising solution, aimed at merging the advantages of conventional internal combustion engines (high reliability, energy density of the fuels) and electric motors (high low-end torque, no tailpipe emissions). Anyway, the environmental and economical sustainability of hybrid powertrain strongly depends on the different concepts (mild hybrid, full hybrid, plugin hybrid), kind of route (city driving, highway driving, …) and driving style. A proper optimization in terms of concepts, components and strategies is then mandatory to obtain valid hybrid solutions.
Short description and objectives of the research activity:	The research project concerns in the study, optimization and step-by-step hybridization of a city car powertrain. The original propulsor is not featured with any electric motor, and consists of a small-displacement turbocharged gasoline engine. In the first part of the research a thorough analysis of the state of the art on hybrid electric vehicles (HEVs) will be carried out, on both scientific literature and commercial applications, aimed at identifying limits and improvement capabilities. The experimental part will start with the characterization of the original engine *as it is* to obtain a baseline: performance, indicating analysis and thermal efficiency will be determined. Then, progressive modifications will be carried out: first, an optimized turbocharger will be used instead of the baseline one. Then, the hybridization will start with the turbocompunding: turbine and compressor will be decoupled, and a system composed of generator, motor and batteries will be added. In this layout, exhaust gas enthalpy will be used to recharge the batteries via generator (coaxial to the turbine), while the compressor will be moved by a coaxial electric motor. Finally, a secondary electric motor in parallel to the engine will be installed to assist the thermal unit in generating brake torque. In all the stages, the recalibration of the engine control unit (ECU) is mandatory to improve the performance that the new layouts will offer [3]. Tools like artificial neural networks [4] could be used to explore all the system capabilities, to guarantee an optimized calibration and to decide the thermal and electric energy fluxes that, together, participate in generating the required brake torque. The final target is the realization of a hybrid system that allows higher efficiency and reduced pollutant emissions with respect to the baseline thermal engine [5]. The activity will be performed at the Engine Lab test bench of the Department of Engineering (University of Perugia). In this research activity the candidate will use and control the test bench instrumentation and devices: semi-dynamic engine brake with a dedicated automation for speed/load control and measurement, indicating analysis, fuel metering, pollutant emission analysis. The candidate will develop also algorithms for data analysis and for bench control.

Bibliography:	1. Kalghatgi, G.; "Is it really the end of internal combustion engines and petroleum in transport?", Applied Energy, 225, 965-974 2. Mariani, F.; Grimaldi, C.N.; Battistoni, M.; 2014, "Diesel engine NOx emissions control: An advanced method for the O2 evaluation in the intake flow", Applied Energy, 113, 576-588. 3. Battistoni, M.; Poggiani, C.; Grimaldi, C. N.; "Experimental Investigation of a Port Fuel Injected Spark Ignition Engine Fuelled with Variable Mixtures of Hydrogen and Methane", SAE Technical Paper, 2013-01-0226 4. Petrucci, L.; Ricci, F.; Mariani, F.; Grimaldi, C. N.; Discepoli, G.; Violi, M.; Matteazzi, N.; "Performance analysis of artificial neural networks for control in internal combustion engines", AIP Conference Proceedings 2191, 020129 5. Solouk, A.; Shakiba-Herfeh, M.; Arora, J.; Shahbakhti, M.; "Fuel consumption assessment of an electrified powertrain with a multi-mode high-efficiency engine in various levels of hybridization", Energy Conversion and Management, 155, 100-115
Scientific coordinator (s)	C. N. Grimaldi
Contact (s)	carlo.grimaldi@unipg.it