Title : Static converters dedicated to mini-actuators – from the converter to the network

Context:
Within the activities of the future M2EI team of the Roberval laboratory, an opportunity to link the activities of the LEC (Laboratoire d'Electromécanique de Compiègne) about power electronics and the ones, already developed in the Roberval laboratory, about mini-actuators is appeared. This opportunity concerns more precisely the power supply of these actuators for which it would not only be interesting to explore the possibilities of improving efficiency and integration of the static converters but also to work on the topology of these converters by considering also the implementation of storage elements.
Indeed, the small actuators developed in this activity are required to operate in a coordinated networked manner and intelligent energy management due to the simultaneous use of several actuators will improve the efficiency of the system. In addition, the fault tolerance of the proposed architectures can be investigated.
The aim of this thesis is to study generic solutions, having the widest possible application fields, in terms of building blocks structures, control devices, or "system" architecture in the case of a network of converters including storage devices (e.g. accumulators, super-capacitors, …). Nevertheless, this work can be based on the case-study presented in Figure 1, containing most of the problems that are to be dealt with. It is a network of actuators developed during the Jing Xu thesis [XU 16] using permanent magnets placed in housings limiting their movements in X and Y.

In our historical research topics, power electronics has been focused on medium power applications (up to a few tens of kilowatts), with an emphasis on the control aspect of the converter through modulation strategies (PWM) in order to improve the overall performance of the system (load currents quality, disturbances and stress of the passive components – DC link/decoupling capacitors – upstream of the converter, switching losses in semiconductors). On this last point, we can cite work on the generalized discontinuous PWM strategy [NGU 11] (GDPWM). This PWM strategy allows us to divide these losses by 2 in all the usual operating points of the machine fed by an inverter.
In the context of micro / mini-actuators, the problem of efficiency relates essentially to the search for a power supply that does not introduce more losses than the actuator itself. This objective is all the more critical since the useful power is low insofar as the losses in the converter include not only those dissipated in the power structure (transistors, diodes, passives, etc.) but also in the control members.

Technological and scientific issues to overcome:
The scientific topics emerging in this thesis can be divided into three points:
• Optimization of a base converter (module) in a context of low power (and possibly of low voltage available) including the constraint of the control (taking into account the consumption of the controller)
• System-wide optimization in the case of mutualized power supply of a group (array) of actuators (converter topology, centralized or distributed control, EMC, ...)
• Operation of energy storage / retrieval devices on the scale of a converter or converter network.

Key terms: Power electronics, static converters, topologies, mini-actuators, energy storage, integration, control, optimization.

Bibliography:
Our activity in the field of power electronics deals, as mentioned above, with problems similar to those raised by this subject, but here it is sought to orient itself towards applications of very low powers for which a thorough bibliographic search will be necessary to identify a state of the art of static conversion (power electronics) in a context of low voltages (of the order of the volt for example) and low powers.
The techniques required to treat the subject are similar to those encountered in the field of energy harvesting. We can therefore rely on references such as [OTT 02] or [YU 17]. The techniques of miniaturization of the converters and reduction of losses will also have to be investigated:
• Synchronous rectification used in Buck converters for powering microprocessor cores [ACK 95]
• Soft switching and resonant converters (ZVS and ZCS) [JOV 90]
• Use of large-gap semiconductors, more particularly GaN [GUA 17]
From the « system » point of view, the architecture of the converter can be either modular or global: similar solutions or approaches must be investigated in the field of multi-level converters [LI 12] and matrix converters [VI 17].
Taking into account disturbances in a centralized power bus is also necessary to ensure reliable operation of a matrix of actuators and its power supply: a specific bibliography on this subject can be made from [LIS 16] which deals with DC networks interconnecting static converters and discussing the stability of the DC bus and filter problems.

References:
