



Année 2019 / 2020

Thèse de doctorat

Domaine : control engineering

Thématique : systèmes dynamiques hybrides

**Titre/Title :** Control of networked switched systems

**Contexte/ Context:**

Laplace/CODIASE research group (Control and Diagnostic of Electric Systems) has a large experience in energy management and modelling of energy conversion systems. Researches on Power Electronics control and Multisource smart energy management are conducted mixing electrical engineering and control theory implemented in real time controller.

**Présentation du Sujet/ Subject details :**

Hybrid systems are ubiquitous in numerous application fields (power electronics, energy management systems, robotics, chemistry, etc.). They are governed by both continuous dynamics (differential equations) and discrete dynamics (recurrence equations, automata, Petri nets). Very often, they emerge when interacting digital systems (computers, software, switching elements, logical components, etc.) and physical processes. The continuous dynamics usually present the natural evolution of the physical process while, the discrete events are due to the presence of switching elements, transitions, computer codes, operating modes, etc.

We are particularly interested in switched systems which constitute one of the most popular classes of hybrid systems [6], [14]. Switched systems describe the behavior of continuous processes exhibiting different operating modes modeled by different differential equations and a logical law indicating which mode is active. Due to the complexity of switched systems, current literature in control theory mostly consider stability and stabilization problems, [2], [11], [7], [15]. Moreover, the proposed techniques assume that the system's model is exactly known and satisfies some nice properties. Often, switching elements in the physical process are not ideal. In addition, the state variables and inputs are constrained and their measures can be affected by perturbations. Moreover, sampling is needed in order to implement the designed controllers. Finally, the parameters of the systems may be uncertain. These phenomena may lead to poor system performances and even instability when they are not appropriately taken into account.

Several methods based on Lyapunov theory and passivity property have been proposed in the automatic control community for different classes of switched systems in order to tackle the stability and stabilization problems, [4], [17], [19], [20], [21]. Most of the proposed approaches considers continuous-time switched systems with continuous-time switching controllers. Moreover, the passivity based switching controllers are proposed for particular classes of switched systems: the switching controller is time-dependent (open-loop control), the subsystems share the same equilibrium point, the fast dynamics are already stabilized by a PI-controller, [1], [5], [10], [12], [20], [21]. The attempts to implement the existing methods have shown that sampling has a real impact on the performance of controlled systems [10], [13], [18], [16]. In the literature, there exist very few results about sampled-data switching controllers design and implementation [8], [9]. Nevertheless, these methods are proposed for a very particular subclass of switched systems. Moreover, the non-idealities of the studied systems have not been taken into account.

The first step in this thesis consists in using passivity based approaches to analyze the behavior of switched systems. Moreover, the future PhD student will study the applicability of the existing methods in the literature to real systems presenting some model non-idealities. Different applications can be considered: simple or more complex converters architecture, and at a system level DC-bus stability using several renewable energies based sources. This will be an intermediate step for addressing the more complex case of performance sampled-data switching control design. Since in the existing tools for sampled-data switching control design very few tractable numerical methods are provided, we will give a particular interest in providing numerical passivity criteria (that may rely on stability criteria) and design tools for the class of switched systems. More precisely, our objective is to provide LMIs criteria [3] for the design of stabilizing switching laws. LMIs stabilization criteria are very interesting since the control design problem may be addressed using powerful convex optimization tools in Matlab. Finally, an experimental implementation can be achieved thanks to the handling benches available in the laboratory.

The PhD will be organized with respect to the following steps:

- The three first months of the PhD will be dedicated to the study of the state of the art related to the research subject. Indeed, the most recent switching controller synthesis techniques will be reviewed by the PhD student. A comparative study about the performances guaranteed by different methods will be realized. Finally, simulations will be performed using power electronic systems in order to assess the possibility to implement the existing approaches on real systems. Finally, the candidate will provide a report on the realized technical work.
- Implementation of some existing switching controllers on a real power electronic system will be done in the second trimester of the PhD. Of course, the first step will consist on the physical process modeling as a switched system. Thus, some analysis should be done about the obtained model simplifications and imperfections. Moreover, the sampling issue should be overcome in order to implement the designed controllers.
- Following the obtained results, one possible research direction in the second semester of the PhD consists on modifying the existing switching controller design techniques in order to obtain better performances of the closed-loop systems while taking into account sampling and model imperfections. Indeed, the obtained modified controllers will be implemented on the physical system. The results can lead to scientific publications.
- The second year PhD will be in part dedicated to scientific publications writing. From the other hand, the problem of designing new sampled-data switching controllers will be addressed. Theoretical developments as well as simulations will be conducted.
- The first semester of the last year of the PhD will be committed to experimental implementations and validation of the obtained new controllers. Finally, a PhD report must be delivered in the last semester of the PhD.

### **References**

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**Profil recherché / Skills requested:**

Student must be graduated from a Master on control engineer or on electrical engineering.

**Connaissances requises / knowledge background:**

Ideal candidates will have:

1. a good background in mathematics, control and or electrical engineering,
2. a good modeling and simulation experience,
3. experience with MATLAB/Simulink, and real-time simulation platforms and software,
4. good English writing and speaking skills,

**Responsible(s):**

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**Lieu du la thèse et conditions particulières :**

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**Conditions particulières/ Particular conditions: Thesis funded by a French ministerial grant**