PhD Thesis Proposal Form
China Scholarship Council (CSC)/ENS Rennes
Call for projects 2021

FIELD: Applied mathematics and power system engineering

THESIS SUBJECT TITLE:

"Energy management under uncertainty, network and real-time constraints of large-scale fleets of electric vehicles"

1. Single French PhD proposal:

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▪ Thesis proposal

More and more frequent and intense crises, such as natural disasters or pandemics have raised a growing awareness and a strong willingness among citizens on the vital necessity to render our societies more resilient and sustainable. As they constitute the backbone of our societies, ***the transformation of current power systems into resilient smart grids represents a key stage towards this goal***. Such a transition will necessarily involve a paradigm shift in the manner these systems are operated, changing from a centralized approach to a ***highly decentralized, smart and dynamic energy management*** avoiding centralizing elements. In this context, a large number of different actors (e.g. grid operators, aggregators, prosumers, etc.) having potentially contradictory individual objectives (e.g. EV charging cost minimization, grid congestion avoidance, etc.) will be involved in the operation of the smart grids. In addition, strong couplings exist at different levels (local/global) between these actors which belong to an increasingly uncertain environment (due to the massive integration of variable renewables such as solar photovoltaics and wind). This leads to a ***highly-coupled, multi-scale grid management problem presenting multiple sources of uncertainty.*** In parallel, in order to operate power systems closer and closer to the real-time, operational windows are increasingly shortening [CRE2017]. In this context, the techno-economic optimization of energy management strategies aiming at ***minimizing both rescheduling and balancing costs***, while considering realistic conditions (i.e. ***real-time and network constraints, large fleets*** of flexible entities (including storage units)) ***represents a complex optimization challenge that conventional methods are not able to address.*** However, in the absence of suitable methods, widespread time-consuming and expensive grid reinforcements would be necessary, thus leading to a ***prohibitive cost for the large-scale grid integration of renewables and electric vehicles***. The scientific challenge tackled by this PhD thesis relates to the development of efficient, real-time and decentralized energy management strategies. Game theoretical methods, and in particular mean-field game theoretical approaches, have shown such capabilities. However, it seems that such methods have only been applied to simplified problems compared to the more realistic problem considered here [Chen2018; Tajeddini2019]. For instance, such simplified problems are restricted to day-ahead hourly planning, do not include electrical network constraints, or consider that information is known entirely by at least one actor. Hence, this thesis topic will focus on the ***adaption of relevant mean-field game theoretical methods to the considered problem*** modelled as ***a dynamic, stochastic game with incomplete information.*** The adaption of these methods to more complex and constrained problems will necessitate the ***investigation of state-of-the-art methods as well as the development of new methods based on the game theory framework***. The considered case

studies on which the game theory-based methods will be applied will present ***an increasing level of complexity*** in terms of size, dynamicity, uncertainty, and information availability among the different actors**.** They will be based on a realistically large fleet of electric vehicles in the order of ***few thousands to few tens of thousands***, providing vehicle-to-grid services to several actors (distribution grid operator, balancing responsible parties, …).

References

[Chen2018]	Y. Chen, M. U. Hashmi, J. Mathias, A. Bušic, S. Meyn, "Distributed Control Design for Balancing the Grid Using Flexible Loads", *IMA Volume on the Control of Energy Markets and Grids*, Springer, pp.383-411, 2018.
[CRE2017]	French Energy Regulatory Commission, "Deliberation n° 2017-155 - Deliberation by the French Energy Regulatory Commission of 22 June 2017 on guidelines for the French electricity system balancing roadmap", 2017.
[Leyton2008]	"Essentials of Game Theory: A Concise Multidisciplinary Introduction", K. Leyton-Brown and Y. Shoham, Synthesis Lectures on Artificial Intelligence and Machine Learning, Vol. 2, No. 1 , Pages 1-88, Morgan & Claypool, 2008.
[Tajeddini2019]	Amin Tajeddini, H. Kebriaei, "A Mean-Field Game Method for Decentralized Charging Coordination of a Large Population of Plug-in Electric Vehicles", IEEE Systems Journal, Vol. 13, Issue 1, 2019.

Contact

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