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Supervisor information	
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PhD information	
Title	Health and operation aware predictive control
Main topics regards to CSC list (3 topics at maximum)	Energy, resources, and sustainability
Required skills in science and	Control, diagnosis, prognosis. Power/Renewable

engineering	Energy systems

Subject description (two pages maximum)

Model Predictive Control (MPC) is one of the most mature methodology to control uncertain dynamical systems. The method relies on a state-space model which allows to predict the future values of the systems states over a receding horizon. The control algorithm finds a sequence of control inputs that minimizes a given criterion over the receding horizon. Hence, MPC is related to optimal control, but over a finite horizon, and allows to achieve trajectory tracking, control effort minimization, etc.
Model Predictive Control is tailored to systems with predictable disturbances, and is indeed very effective for multisource power systems [1] or power smart grids [2], that is systems for which volatile renewable power sources (wind, solar) generate stochastic powers. However, one of the key issues for the design of MPC is to find a suitable criterion, which results in general of a compromise between tracking performances (reaching a prescribed reference) and the energetic cost. As those items are not easily comparable, one can use an economic criterion based on financial issues [1], or even a service rate, which consists of maximizing the probability that the states (e.g. grid voltages) remain whithin prescribed bounds [3]. However, all these methods ignore two important features:

- There may exist different operating modes with consequently different dynamics or systems configuration; for example a battery can experience charge or discharge, or can be disconnected from the multisource power cell [6]. There also can be a switching between different operating modes when there is a component failure, and, in this case, a diagnosis algorithm is called for [5].
- Model Predictive Control generally ignores the maintenance and prognosis issues which are described in [4]. Very few papers introduce such notions as diagnosis, Remaining Useful Life in their criterion. In general, this is taken in account only for some actuators when the control effort is minimized

Promoting sustainable and clean energy does not only consist of limiting CO2 or nocive gaseous emissions but also to extend the useful life of power systems. The aim of the thesis is to fill in a gap for power and energy systems. Indeed, there exist some papers dealing health-aware MPC, and very few with health-aware MPC for power and energy systems. Moreover, these works are not related to operating mode management.

A multisource power cell, including an hydrogen electrolyzer and a Proton Exchange Membrane Fuel Cell (PEMFC) and renewable power sources, will allow to apply the algorithms developed during the thesis.

The sketch of the thesis is as follows:

- Complete a bibliography on health-aware Model Predictive Control

- Design operating mode management supervisor and prognosis criteria for multisource power systems; this work will be done in coordination with other PhD students
- Embed the resulting constraints and subcriteria in Model Predictive Control
- Find numerical tools to solve the optimal control problem and demonstrate convergence or feasibility

A toy example (an electrical motor) will be first used to understand and implement health-aware MPC algorithms. Then, a multisource power cell, including an hydrogen electrolyzer, a Proton Exchange Membrane Fuel Cell and renewable power sources (Regional Project MODIS-H2), will allow to validate the algorithms developed during the thesis.

The PhD student will be cosupervised by Dr. Anne-Lise Gehin (Polytech-Lille/Cristal). A short and non exhaustive list of related publications by both authors is given below.

References

[1] J.-Y. Dieulot, F. Colas, L. Chalal, G. Dauphin-Tanguy, Event-triggered variable horizon supervisory predictive control of hybrid power plants, **Control Engineering Practice**, 34, 61-67, 2015.
[2] J. Morin , F. Colas , X. Guillaud , S. Grenard S., J.-Y.Dieulot , Embedding OLTC nonlinearities in predictive Volt Var Control for active distribution networks, Electric Power Systems Research,2018
[3] J. Buire, F. Colas, J.-Y. Dieulot, X. Guillaud, L. De Alvaro, Confidence level optimization of DG piecewise affine reactive power controllers in distribution grids, submitted
[4] B. Ould Bouamama, N. Chatti, A.-L. Gehin. SBG for Health Monitoring of Fuel Cell System. In Renewable Energy: Generation and Applications - Springer Proceedings in Energy. Springer, Cham. July 2014.
[5] I. Abdallah, A.-L. Gehin, B. Ould Bouamama. On-line robust graphical diagnoser for hybrid dynamical systems. Engineering Applications of Articial Intelligence, 2018.
[6] I. Abdallah, A.-L. Gehin, Belkacem Ould Bouamama. Event driven Hybrid Bond Graph for Hybrid Renewable Energy Systems part I: Modelling and operating mode management. International Journal of Hydrogen Energy, December 2017.