PhD thesis proposal, CSC 2020

Title: Joint modeling of predictive maintenance and automatic control of dynamic systems

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Keywords: Predictive maintenance, automatic control, stochastic modeling, dynamic system, energy management

Description:

The increase of energy cost and the environmental aspects lead us to rethink about our energy consumption, notably in the fields of construction and industry. The use of renewable energy sources such as wind or photovoltaics is one possible solutions. This rises the problem of how to integrate these new resources within the current production (given mostly from nonrenewable energy sources such as nuclear, hydroelectric). How to optimize the management of these mix of energies for the consumption needs? To answer to these problem, one need to design new static converters which can simultaneously deal with multiple energy flow, and/or load and unload various types of batteries following different requirements. At the heart of these new static converters, in addition to power electronics equipments, the logic of their control plays a key role in maintaining their performance, availability and maintainability. Static converters, energy storage systems deteriorate with time and usage conditons. By this aspect, these systems are critical. Up to now, the logic (law) of their control does not include this type of information. Here, the challenge of our project is to integrate the evolution of the degradation of these systems in synthesizing more sophisticated control laws and less impacting from the view of deterioration.

The proposed solution in the framework of this PhD thesis is based on a representation mode similar to those of the transfer functions traditionally encountered in systems theory (eg. root locus representation). The objective is to jointly synthesize the control and maintenance strategies including all the achievements and results of stochastic modeling of degradation developed in our laboratory. This objective raises several questions such as:

- What is the impact of the stochastic degradation on the root locus of the controlled system?
- Within this new representation mode, is it possible to define different zones describing the system behavoir form its new state to its failure state. How do we evaluate the remaining useful lifetime of the system ?
- How does this representation mode facilitate a decision-making (eg. trigger a maintenance action, reconfigure the control law, ...) or even to improve it?

The project realization requires knowledge in the areas of reliability, maintenance and control. We will rely on stochastic processes coupled to differential equations to assimilate the working and failure behavior of controlled systems. We can easily imagine that a system can be described by a set of differential equations whose parameters are affected over time by an underlying degradation mechanism. Based on this framework, we will study the impact of stochastic degradation on the root locus of the controlled system. These studies allow to define different zones from nominal operation to failure state of the controlled system, and therefore to estimate its remaining life. Here, probabilistic calculations skills will be used. The aims of this analysis is to make a maintenance decision and/or to reconfigure the control law. We will consider predictive strategies for maintenance of such systems, conventional control laws (PID, LQR, LQG ...) for their control. Finally, Monte Carlo simulation techniques of and/or Matlab Simulink, Stateflow, may be used. They will be on the one hand (i) as a verification tool to valide analytical formulations, and on the orther hand (ii) as a complementary technique where analytical developments will be impossible.

Some related works:

1. Ma, J., Fouladirad, M., & Grall, A. (2018). Flexible wind speed generation model: Markov chain with an embedded diffusion process. *Energy*, 164, 316-328.
2. Huynh, K. T., Grall, A., & Bérenguer, C. (2019). A parametric predictive maintenance decision-making framework considering improved system health prognosis precision. *IEEE Transactions on Reliability*, 64(1), 375-396.

3. Langeron, Y., Grall, A., & Barros, A. (2017). Joint maintenance and controller reconfiguration policy for a gradually deteriorating control system. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, 231(4), 339-349.
4. Huynh, K. T., Langeron, Y., & Grall, A. (2017). Degradation Modeling and RUL Estimation of Deteriorating Systems in S-Plane. *IFAC-PapersOnLine*, 50(1), 12249-12254.
5. Nguyen, D. N., Dieulle, L., & Grall, A. (2015). Remaining useful lifetime prognosis of controlled systems: a case of stochastically deteriorating actuator. *Mathematical Problems in Engineering*, 2015.

Research team: The Systems Modelling and Dependability Laboratory (webpage: http://lm2s.utt.fr/en/index.html) is part of the Charles Delaunay Institute. This institute coordinates all the research activities in theuniversity. The Systems Modelling and Dependability is organised into two main research projects: decision and diagnostic in non-stationary environment and stochastic models for reliability andmaintenance. The applicant will be involved in the last team.

Collaborations:

- Christophe Bérenguer from GIPSA-INP Alpes Grenoble University,
- Anne Barros from Norwegian University of Science and Technology.

Candidate profil: We are looking for a candidate who holds an MSc degree and is familiar with one or more of the following themes:

- automation,
- stochastic modeling,
- applied mathematics (probability-statistics-simulation).

A good level of the English andor French language is appreciated.