Master thesis proposals for the Department of Control Engineering and System Analysis (SAAS)

Academic year 2022-2023

Content

1. Hybrid modelling of lithium-ion batteries for accurate state-of-charge and state-of-health estimation

Supervising team

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Context of the work:

Renewable energies and electric transportation are the cornerstones for developing a sustainable future society. Energy storage is fundamental in this context, in order to store surplus of energy and use it when the wind does not blow, or to produce vehicles that do not pollute the environment. Among the possibilities, lithium-ion batteries are the technology of choice given their high energy capacity and efficiency. However and in contrast with other battery technologies, the benefits of lithium-ion batteries come at the price of careful monitoring requirements.

Among the different tasks of a monitoring system for lithium-ion batteries, the estimation of the state-of-charge (SOC) and state-of-health (SOH) is possibly the most important one. The SOC for a battery is equivalent to the level indicator for a fuel tank, i.e. it is the energy available with respect to the total energy. The SOH is related with the age of the battery, and it decreases continuously with battery usage. Several approaches notably based on state observers have been developed for SOC estimation. However, these observers rely on an accurate model of the battery, which is difficult to obtain especially as multiple and intertwined degradation processes start to occur. To account for these processes is then key to track/model the evolution of the SOH as the battery ages.

The objective of this thesis is to study the incorporation of machine learning techniques to learn from data the degradation of the battery while resorting to a physics-based model to incorporate the electrochemical principles behind battery standard operation. The work will rely on a detailed battery cell simulator as well as experimental measurements.

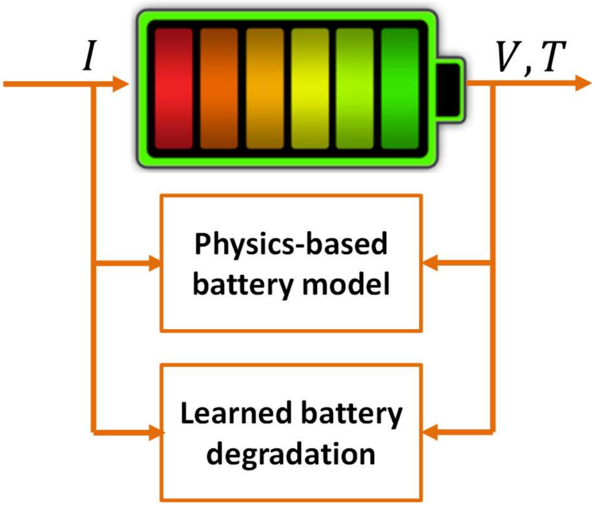

Figure 2. Simple diagram of hybrid physics-machine learning model for lithium-ion batteries.

Requested skills: Basic knowledge in programing and control theory.

2. "Ball in the tube" device for teaching of control engineering

Supervising staff

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Context:

The framework of the project is the teaching of control system theory to future engineers. The goal consists in designing new modular, evolving, and open-source solutions to provide a better, more practical learning experience to the student.

Different prototypes have been realized, including a prototype using a DC motor as an actuator and a data acquisition board for the real-time implementation of the controllers and another using a brushless motor and a Python-based software for the controller implementation. Different distance sensors were also tested to measure the position of the ball: an IR sensor and a laser sensor.

The objective of this project is to analyze the existing setups and to come up with a more modular and flexible solution both regarding the electronic part and the mechanical part of the device. Particular attention will be paid to the modeling of the device and the adequacy between the model and the behavior of the real process. With regard to the mechanical part, various options should be investigated to ensure that the setup can behave either like a type 0 or a type 1 (integrating) process.

Key objectives:

- design of modified experimental setup (SolidWorks, 3D printer, electronics …)
- design of the power supply & cable management
- implementation of a control strategy
- setup of some didactic experiments & their related teaching materials

Requested skills:

- quick & autonomous learner in a dynamic environment
- team player, creativity
- basic knowledge in control theory, digital signal processing, electronics

3. Design of new didactic devices for teaching of control engineering

Supervising staff

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Context

The framework of the project is the teaching of control system theory to future engineers. The goal consists in designing new modular, evolving, and open-source solutions to provide a better, more practical learning experience to the student.

A set of didactic devices is under development including a self-balancing robot, a fluid mixer,…. The aim of this project consists in modifying/designing new features involving mechanical, electrical, as well as software parts in order to end up with a fully functional device that can be used both for teaching labs and for demos.

Key objectives:

- selection of the sensors/actuators
- design of the signal conditioning / acquisition stages
- design of the experimental setup (SolidWorks, 3D printer …)
- design of the power supply & cable management
- implementation of a control strategy (Arduino/C programming or Matlab/data-acquisition board)
- setup of some didactic experiments & their related teaching materials

Requested skills:

- quick & autonomous learner in a dynamic environment
- team player, creativity
- basic knowledge in control theory, digital signal processing, electronics

4. Health monitoring of electromechanical actuators for the flight control surfaces of airplanes

Supervisors:

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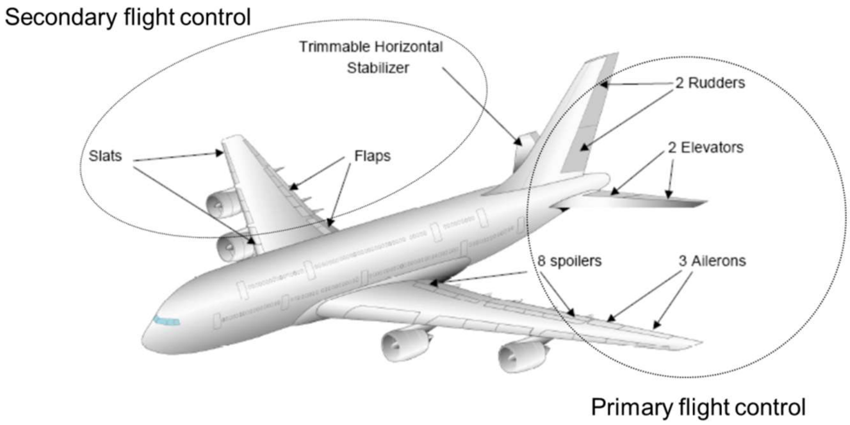
Context of the work

This work takes place in the framework of the MONISA project performed in collaboration with SABCA. In order to make aircraft lighter and hence reduce the kerosene consumption, the trend is to replace hydraulic actuators by electromechanical actuators (or EMAs). However, to keep the same level of availability and safety, EMAs must be equipped with a health monitoring (HM) system. The latter should be able to detect malfunctions at an early stage, and follow their evolution, in order to allow planning maintenance operations in due time. The monitoring system should have a small probability of false alarms in order not to affect the plane availability

The aim of this master thesis is to contribute to the development of such a health monitoring system by exploiting the in-flight data set and by developing estimation schemes accounting for state and parametric constraints.



Work to be done

1. Getting acquaintance with the problem setting and the existing simulator of EMA
2. State of the art in data-based fault detection/isolation methods for EMAs and in the design of health monitoring systems based-on constrained state and parameter estimation
3. Determination of fault indicators on the basis of the in-flight phases using the state/parameter estimation.
4. Inclusion of constraints in the state/parameter estimation
5. Validation of the HM system resulting from steps 3 and 4 using data generated from the simulator and possibly from test-benches at SABCA.

Requested skills

Good understanding of control theory, programming skills in MATLAB/SIMULINK

5. Wind farm modeling with a view to dynamic grid simulations aimed at assessing frequency regulation strategies

Supervising team

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Context

This master thesis takes place in the framework of the PhairywinD project which groups nine Belgian Universities and research institutions and aims at training a group of researchers able to address the present challenges in the offshore wind energy sector.

With the increased share of wind farms in the production of electricity, it is important to ensure that these wind farms can provide ancillary services. To assess this feature, dynamic simulations of the power grid are needed. Such simulations call for wind farm models that capture the effects of the variability of wind intensity and direction as well as different levels of wind penetration.

Problem statement

The goal of the work is to perform a comparative study and to adapt wind farm models to be used in the framework of dynamic grid simulations aimed at evaluating the effectiveness of frequency regulation strategies. Such models should include a statistical characterization of the variable performance of wind farms for providing a specified reference power. This variability with respect to wind intensity and direction is notably due to the different operating modes of the wind turbines and to the wake effects. It can be characterized by using the software FAST.Farm and TurbSim developed by the National Renewable Energy Lab (NREL) in the US. On the other hand, dynamic grid simulations are typically performed with software like Eurostag or Simscape Power Systems, and they use simplified wind farm models. The problem is to determine simple wind farm models that are sufficiently representative to cover the variable performance of wind farms when used in dynamic grid simulations and to be able to adjust them to a specific wind farm setting in a systematic way.

Work to be done

The student should

1. perform bibliographic research on wind farm models used in dynamic grid simulations
2. get familiar with the software FAST.Farm and TurbSim to simulate the aerodynamic power within a wind farm and characterize its variability
3. evaluate and possibly adapt simplified wind farm models for solving the above-mentioned problem. This calls for the development of a tuning methodology for each model based on point 2
4. compare the most effective models for assessing a given frequency regulation strategy for a simple grid fault scenario

Requested skills

Good basis in control/electrical engineering; good programming skills (in MATLAB/SIMULINK)