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

Academic year 2023-2024

Content

1.Degradation detection and localization in battery packs

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 the sun does not shine, or to produce vehicles that do not pollute the environment when they are on the roads.

Among the possibilities, lithium-ion batteries are the technology of choice given their high energy capacity and efficiency. However in contrast with other battery technologies, the benefits of lithium-ion batteries come at the price of careful monitoring requirements. Indeed, faulty cells in a battery pack can have catastrophic consequences including fire.

Objective of the thesis

The objective of this thesis is to develop a monitoring system that is able to detect and localize the degraded or weak cells within a pack on the basis of available voltage, current and temperature measurements. Both synthetic data obtained from a realistic battery pack simulator, and real data recorded on a 4-cell battery pack will be exploited to determine features that can be extracted from the measurements, or from combinations of measurements, and that exhibit pack malfunction. Next, appropriate classification tools will be investigated in order to decide on the healthy or degraded state of the pack and to localize the degraded cell/cells by processing the features extracted from the measurements. Various degradation levels and types will be considered in order to characterize the sensitivity to each fault.

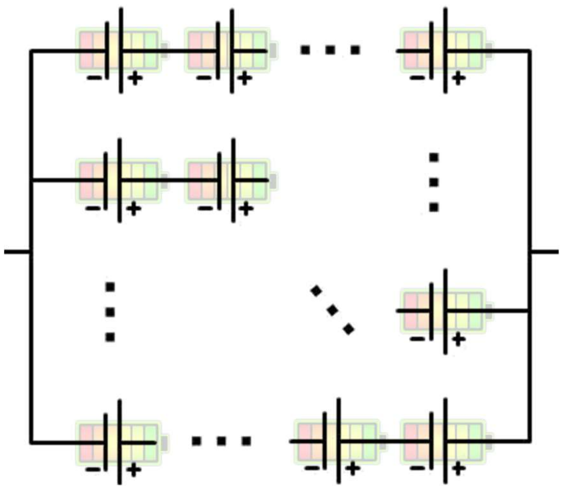

Figure 1. Battery pack.

Work to be done

The student should

1. perform a bibliographic search on fault/degradation diagnosis for battery packs,

2. generate synthetic data for heathy pack operation and for various degradation types and levels,
3. Use measurements and/or appropriate functions of the measurements to generate features that exhibit faulty/degraded behaviour,
4. Develop a classification method that decides on the pack state by processing the features extracted from regular measurements.

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

Supervising team

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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

3.Fault tolerant active power control of wind farms

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. Therefore, wind farm operators should be able to control the delivered active power at best by limiting the fatigue loads while meeting the reference that they have previously announced to the Transmission System Operator. The controller should also adapt when some wind turbines are stropped due to maintenance operations or due to faults.

Problem statement

The objective is to develop a control strategy that shares the active power production between the wind turbines is such a way that fatigue loads are minimized in some sense. Different criteria could be considered, like favouring winds turbine for which the cumulated damage is the most important, or trying to minimize the additional cumulated fatigue loads on the farm. Such loads are linked to wake effects as the latter induce increased wind turbulence and hence extra loads on the wind turbine components. To achieve the objective, the software FAST.farm and TurbSim developed by the National Renewable Energy Lab (NREL) in the US, will be used. Different control strategies will be implemented, validated and compared.

In a second phase, adaptation of the control strategies to account for the unavailability of some of the turbines within the farm will be considered. This unavailability might be due to faults or to maintenance operations.

Work to be done

The student should

1. perform a bibliographic search on active power control for wind farms,
2. get familiar with the software FAST.Farm and TurbSim to simulate the aerodynamic power within a wind farm and to evaluate the fatigue loads on the different turbines,
3. develop, implement and validate control strategies that meet the above-mentioned objectives,
4. analyze the simulation results and deduce the pros and cons of the different control strategies.

4.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. Due to the large size of the grid and its complexity, wind farm models in power system assessments are simplified, neglecting the 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. The latter variability can be characterized by using the software FAST.Farm and TurbSim developed by the National Renewable Energy Lab (NREL) in the US.

Dynamic grid simulations are typically performed with software like Eurostag or Simscape Power Systems, which use the previously mentioned 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 a bibliographic search 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