MA1 projects at SAAS – Academic year 2017-2018

1. Pitch control for mechanical load reduction upon grid disconnection

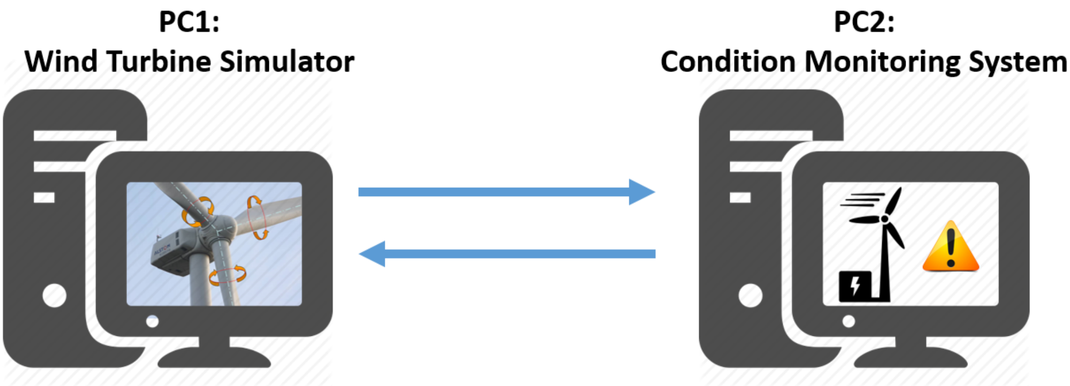
Supervisors: Sandra Paola Vasquez Rodriguez (Sandra.Paola.Vasquez.Rodriguez@vub.ac.be) and Michel Kinnaert (Michel.Kinnaert@ulb.ac.be)

Mitigating extreme mechanical loads in wind turbines is of paramount importance in order to reduce maintenance costs. Previous work has shown that pitch control may be useful to reduce extreme mechanical loads that are observed upon occurrence of faults in the network that induce abrupt turbine disconnection. However, the considered studies do not take into account the backlash in the gear. The aim of this project is to take into account this phenomenon in the controller design and to study how it affects control performance.

2. Contribution to the design of a demonstrator for a wind turbine condition monitoring system

Supervisors: Sandra Paola Vasquez Rodriguez (Sandra.Paola.Vasquez.Rodriguez@vub.ac.be) and Michel Kinnaert (Michel.Kinnaert@ulb.ac.be)

The objective is to contribute to the development a demonstration platform made of two software tools running on two PC's interacting with each other. The first PC (PC1) should run the wind turbine simulator, where the data acquisition system available in most wind turbines (i.e. the SCADA system) will be emulated in order to generate synthetic data. Both normal and faulty operating modes will be considered. The second PC (PC2) should run the condition monitoring system able to process on-line the synthetic data and issue a diagnosis on the state of health of the different wind turbine components (sensors, actuators, etc.).



The focus will be on the wind turbine simulator. An available wind turbine simulator runs in the MATLAB/SIMULINK environment, and it is based on the FAST software developed by the National Renewable Energy Laboratory (NREL, USA). The aim of the project is to introduce additional faulty scenarios in the simulator and to develop a friendly user interface for this simulator, starting from the work that has been done previously on this interface. The simulation of the data acquisition system and the communication interface with the PC2 should also be developed.

3. Battery test rig upgrading for fading experiments

Supervisors: Alberto Romero (Alberto.Romero.Freire@ulb.ac.be) , Laurent Catoire (Laurent.catoire@ulb.ac.be) and Emanuele Garone (egarone@ulb.ac.be)

The department is currently developing models and strategies to capture and mitigate lithium ion batteries' capacity and power fade. Regarding modeling, several approaches are being used, such as equivalent circuit and electrochemical models for dynamic simulation of short-term behavior (i.e., temperature, voltage, state of charge, lithium concentration, etc.), coupled with long-term fading models. These degradation models are either empirical or first-principle-based, and describe the electrochemical reactions or their effects that modify the state and availability of lithium ions.

In addition to battery modeling and simulation, the aim of the department is to develop novel control strategies capable of keeping the internal states of the battery within a range that ensure that degradation is minimized, while still being able to use the full capacity of the battery, even at increased C-rate, i.e., power input or output.

So far, these control strategies have proved successful in simulation. The natural next step is to implement in the department's test bench the algorithms in a real battery. In fact, preliminary tests comprising several charge and discharge cycles have already been carried out in the laboratory with promising results. These show that the controller can reliably operate the battery within the safe region and, for instance, minimize charging time.

However, in order to actually prove the benefit of the novel control approach, tests with significant number of charge-discharge cycles in a controlled environment must be undertaken. Periodically, capacity and power fade checks should be effectuated to monitor the state of health throughout the tests. Only then, and by comparison with traditional charge protocols such as constant-current-constant-voltage (CCCV), the benefits of the novel approach can be determined.

As pointed out, the tests should be effectuated in controllable operating conditions, which is generally limited to the control of environmental temperature and heat transfer conditions (convection). In the literature, temperature is fixed at different levels, each one used for a separate test. Common conditions are 25, 45 and 65°C, but for specific applications predetermined temperature profiles may be necessary.

Currently, however, the laboratory test-bench does not support environmental conditions control. It does have temperature sensors, monitoring the environment and the battery surface. Thus, a modification of the existing one, or a new design of test bench is required. Either one should be capable of hosting extended life-cycle tests, in temperature environments from 15 to 65°C in a controlled fashion. Regarding the duration of the test (number of cycles), the rig should be capable of carrying out the tests autonomously and without human intervention for prolonged periods, up to days. Regarding the environmental conditions, Peltier cells may provide a means for temperature control by voltage manipulation.

4. Benchmarking of system identification methods

Supervisors: Emanuele Garone (egarone@ulb.ac.be) and Ivan Markovsky

The project has two objectives:

1. build a system identification benchmarks database and
2. compare existing identification methods on the benchmarks.

The benchmarks will be selected from practical stands, available at the laboratory of the Control Engineering and System Analysis Department of the ULB and the ELEC department of the VUB. The system identification methods to be compared are a range of subspace and prediction error methods (available in the System identification toolbox of MATLAB), the frequency domain identification toolbox, and a method based on structured low-rank approximation (available from http://slra.github.io).

5. Power System Stabilizer Tuning Procedure for Enhancing Power System Stability

Supervisors: Johnny Leung (Johnny.Leung@ulb.ac.be), and Michel Kinnaert (Michel.Kinnaert@ulb.ac.be).

Context of the work

In large-scale interconnected power systems, poorly damped low-frequency oscillations tend to emerge within the systems after the occurrence of disturbances. As a result, the generators of one area of the system start to exchange power with the generators inside another area of the system for a long period of time. This phenomenon, known as *inter-area oscillation*, can be particularly harmful to the stability of the power system, and endanger the security of supply.

To mitigate the effect of those oscillations, a controller, called *Power System Stabilizer* (*PSS*), is added to some generators. The PSS takes as input the speed deviation of a generator, and adapts the value of the field voltage accordingly. This has the effect of adjusting the power produced by the generator in order to reach a new steady state faster.

In the industrial world, PSSs are generally tuned on a single-machine infinite-bus power system model. This approach is sufficient to improve the dynamic behavior of the system, but the PSSs can actually be exploited in an even better way if they were tuned on a model of the whole interconnected power system.

The objective of this project is to implement some procedures for tuning the parameters of a PSS on a multi-machine power system model, and compare their performances. Priority will be given to the procedures that are computationally tractable with large-scale power system models.

Description of the work

1. Understand the role of a PSS in power systems
2. Perform a bibliographical study on existing PSS tuning procedures
3. Implement different PSS tuning procedures, and compare the results in terms of
    a. improvement in the dynamic behavior of the power systems
    b. computational effort

The work will be carried out on standard power system models implemented inside the toolbox PSAT (available from http://faraday1.ucd.ie/psat.html).

6. UAV Navigation in Crowded Environments in the Potential Function Framework

Supervisors: Mehdi Hosseinzadeh (Mehdi.Hosseinzadeh@ulb.ac.be), Tam Nguyen (tanguyen@ulb.ac.be), and Emanuele Garone (egarone@ulb.ac.be).

Context of the work

In recent years, Unmanned Aerial Vehicles (UAVs) have received an increasing amount of attention from the scientific community. Their applications range from simple navigation missions to complex aerial robotic construction missions. However, UAVs are usually subject to constraints (e.g. input saturations, obstacles, crowds, etc.), which must be dealt with to maintain safety, reliability, and stability properties of the UAVs.

The objective of this project is to develop a path planner for a UAV to autonomously navigate an area crowded with moving obstacles (see figure below).

Description of the work

The student will be asked to:

1. Understand the potential field philosophy.
2. Design a potential field-based path planning algorithm for fixed obstacles; then, to extend it for the case of moving obstacles.
   Note: Only the kinematics will be considered in the design procedure.
3. Experimentally implement the proposed algorithm.
4. Develop a MATLAB toolbox to make the proposed method easy to use for a wider public.

Advanced works will be to:

1. Understand the concept of invariance level sets.
2. Incorporate the dynamics of the UAV in the design procedure.
3. Develop a general path planner (with considering both dynamics and kinematics) for UAVs in the presence of moving obstacles on the reference governor philosophy.