Control Applications for Power Generation: A Tutorial, Some Advanced Topics and Many Open Problems

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Description: All complex power production applications nowadays, from gas and steam turbines, to wind turbines, to integrated gasification combined cycle, require some degree of closed-loop control, for stability and performance.

Typically, a well-tuned PID was sufficient for the first generation of control solutions where, generally, the problems in complex plants where related to performance improvement of different local loops. While moving towards more complex applications, more stringent requirements and systematic design of plants to meet the specifications while minimizing cost, model-based multi-objective control design is becoming more frequently the design method of choice.

In power generation applications, model-based control design methods have to address typical problems associated with complex applications such as large order models and actuator nonlinearities, but also specific issues - dynamic nonlinearities, mode coupling or limitations due to conflicting control objectives. The performance obtained by these controllers is crucial in certain industrial applications for which feedback control is a vital component of the overall operation.

In this workshop we present both a tutorial and a set of open control problems in two such applications: a wind turbine control problem and the control of thermoelastic systems.

Part I: Wind Turbine Control

Control applications for wind turbines have received increased attention in the past decade. The decrease in cost of energy while increasing the size of the turbine has prompted intense interest towards larger and more efficient machines. However, the efficiency of wind power does not scale simply in this case and control plays a significant role in increasing the size of the machine while decreasing the structural loads and improving the efficiency of the rotor.

Control challenges in this application are related to the highly nonlinear nature of the blade aerodynamics in turbulent wind and its coupling with the structural dynamics. In addition, nonlinear limitations imposed by the actuators (magnitude, rate, duty cycle) limit the achievable performance of the controllers, which is also coupled with the design of the different components. In this workshop we introduce the basics of the wind turbine dynamics, review the control objective and the state-of-the-art in addressing some of the design challenges, trade-offs and issues which affect a wind turbine controller performance and open problems of interest in the wind turbine industry currently or in the near future. This presentation will point out why certain problems are hard and what are the current design limitations, will introduce benchmark examples to motivate the search for new control design methods, and will also review control validation methods using high-fidelity simulators and implementation concerns.

Part II: Control of Thermoelastic Systems

The control of industrial systems usually attempts to maximize performance (e.g. efficiency, throughput, specific energy consumption) while maintaining stability and physical integrity. Typically, maximum performance is obtained for operating conditions reaching a physical limit at one or more of the system components and the controller goal is to achieve the maximum performance consistent with the level of uncertainty in process variations and disturbances.

In a model-based control approach, increased model accuracy implies reduced uncertainty. Control applications in power generation and chemical processes are characterized by large temperature excursion of components like tanks, tubes, reservoirs, rotors and casings, which are limited by maximum level of temperature, stresses, pressure, differential expansion. High-fidelity physical models for thermoelasticity (coupled thermal dynamics and elasticity) are usually developed during the design process of these components, but their dimensionality is excessive for current control architectures. As a consequence, model-based controls typically recourse to lower fidelity models that penalize the achievable performance. A systematic methodology for obtaining reduced order models directly from the design models will greatly reduce the development cycle for high performance model-based controllers.

In this workshop we will focus on model reduction techniques for thermoelastic systems, pointing advantages and limitations of current techniques. Benchmark thermoelastic models and performance evaluation criteria will be introduced to encourage the developments of new model reduction techniques suitable for implementation in current control architectures.

Please add time stamps to this schedule. Start times are typically between 8 am and 9 am. There is usually at least 1 morning coffee break (15-20 min). There is usually a 60-90 minute lunch break. Finally, workshops typically end between 5 and 6 pm.

Schedule application 1:

1. Aerodynamics of a horizontal-axis wind turbine	8:00 – 9:00
3. High-fidelity simulators (aerodynamics)	9:00 – 9:30
2. Structural dynamics and wind-turbine performance	9:45 – 10:45
4. High-fidelity simulators (structural dynamics)	10:45 – 11:15

5. Models for control design	11:15 – 11:30
3. Control design objectives	11:30 – 12:00
4. Current approaches to control design; limitations, trade-offs	13:00 – 13:30
6. Open problems	13:30 – 14:00

Schedule application 2:

1.Thermoelastic models for isotropic materials	14:00 – 15:00
2.Thermoelastic operational limits of industrial components	15:00 – 15:30
3. Model reduction objectives	15:30 – 16:15
4. Current approaches to model reduction; limitations, trade-offs	16:15 – 17:00
5. Benchmark problems for nonlinear model reduction	17:00 – 18:00

Length: 1 day

Audience: expected to be formed of graduate students in their beginning of their studies looking for new problems and applications to address, as well as new faculty in search of establishing graduate programs. The workshop will be "hands-on" in the sense of providing the current state-of-the-art in control design, open problems of interest for the industry and discuss validation and implementation constrains. At the end of it the audience should be able to start independent research and provide advanced solutions on a relevant topic of industrial interest.