lmeca2675 — Robust Optimization of Energy Systems

2022

5.00 credits	30.0 h + 30.0 h	Q1

Teacher(s)	Contino Francesco ;
Language :	English
Place of the course	Louvain-la-Neuve
Main themes	In a design phase, engineers often rely on simulations and optimize a set of parameters towards one or several objectives. This procedure becomes expensive as they tackle the many requirements (flexibility, efficiency, resilience, ...) of novel concepts and try to reach the required level of fidelity. Yet, more often than not, they rely on deterministic simulations—not considering the uncertainties of the inputs or the models. In some instances, the quality of an optimum can be dramatically affected by a slight change in the working conditions (boundary or operating conditions). Taking these uncertainties into account leads to robust optimization but adds a significant computational overhead, also known as the curse of dimensionality. This course aims at training future engineers as user of robust optimization with a specific application to energy systems: balance of resources that are converted, stored, or transported to meet user needs. These systems have three inherent challenges: they contain multiple (sometimes thousands) parameters, they couple different sectors (e.g. transport and industry), and they include various types of uncertainties. There are four main themes each related to a question an engineer should address as a user of robust optimization: 1. How to select the uncertainty propagation technique for the case being studied? 2. What is the best (and how to define “best”) optimizer for a specific model and the considered objectives? 3. How to evaluate and analyze the output of a robust optimization? 4. How to deal with models that have a high computational cost (mitigate the curse of dimensionality)?
Learning outcomes	**At the end of this learning unit, the student is able to :** In consideration of the reference table AA of the program "Masters degree in Mechanical Engineering", this course contributes to the development, to the acquisition and to the evaluation of the following experiences of learning: · AA1.1, AA1.2, AA1.3 · AA2.1, AA2.2, AA2.3, AA2.4, AA2.5 · AA3.1, AA3.2 · AA5.3, AA5.4, AA5.5, AA5.6 · AA6.1, AA6.2, AA6.3, AA6.4 By the end of the course, the students will be capable to : i) apply uncertainty propagation techniques to the design of energy systems, ii) select robust optimization algorithms for energy systems and analyze their output and iii) successfully deal with the complexity and high computational cost associated with the modeling and optimization of energy systems.
Evaluation methods	The evaluation consists of the active participation in class (30%), a project (30%), and an oral exam (40%). For the second session, the oral exam supersedes the other scores (100% of the final score) except if the student asks to keep the scores of the participation in class and the project. In that case, the same score split as above is kept.
Teaching methods	Lectures (including flipped classroom, and case analysis) Exercises: sessions with a teaching assistant, and homework. The exercises are either direct applications of the theory (with an objective to familiarize the student to practical computation methods, and to familiarize them to typical orders of magnitude), or they will rely on the creativity of the student to use the concepts learned in the class to tackle new problems or methodologies not explicitly studied during the lectures
Content	Each of the following points will be directly coupled to energy systems through examples or exercises. 1. Uncertainty quantification Reminder on statistical analysis; Monte Carlo uncertainty propagation; Advanced techniques: Polynomial chaos; Sensitivity coefficient. 2. Optimization Understand the tradeoff between exploitation and exploration; Categories of optimizers (gradient-based and metaheuristic);

	Hybrid optimizers. 3. Robust optimization Efficient combination of uncertainty quantification and optimization; Evaluation of the results (Pareto front); Challenges. 4. Surrogate modeling Principles and limitations; Kriging; Support Vector Regression.
Inline resources	Moodle website
Bibliography	Obligatoires Notes du cours disponibles sur le site Moodle du cours et au SICI Transparents du cours disponibles sur le site Moodle du cours Ennoncés d'exercices, disponibles sur le site Moodle du cours Conseillé Probabilistic Design for Optimization and Robustness for Engineers, B. Dodson, P. C. Hammett, R. Klerx, 2014, Wiley
Faculty or entity in charge	EPL

Programmes containing this learning unit (UE)				
Program title	Acronym	Credits	Prerequisite	Learning outcomes
Master [120] in Mechanical Engineering	MECA2M	5		