Course guide
200638 - OSME - Optimisation in Energy Systems and Markets

Last modified: 23/06/2025

Unit in charge: School of Mathematics and Statistics
Teaching unit: 715 - EIO - Department of Statistics and Operations Research.

Degree: MASTER'S DEGREE IN STATISTICS AND OPERATIONS RESEARCH (Syllabus 2013). (Optional subject).

Academic year: 2025 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: ALBERT SOLÀ VILALTA

Others: Primer quadrimestre:
ALBERT SOLÀ VILALTA - A

PRIOR SKILLS

Basic background in linear, integer and non-linear optimisation is recommended. However, the course is self-contained, all the concepts necessary to follow the course are explained in class.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
1. CE-2. Ability to master the proper terminology in a field that is necessary to apply statistical or operations research models and methods to solve real problems.
2. CE-5. Ability to formulate and solve real problems of decision-making in different application areas being able to choose the statistical method and the optimization algorithm more suitable in every occasion.
Translate to english
3. CE-7. Ability to understand statistical and operations research papers of an advanced level. Know the research procedures for both the production of new knowledge and its transmission.
4. CE-9. Ability to implement statistical and operations research algorithms.
8. CE-3. Ability to formulate, analyze and validate models applicable to practical problems. Ability to select the method and / or statistical or operations research technique more appropriate to apply this model to the situation or problem.
9. CE-6. Ability to use appropriate software to perform the necessary calculations in solving a problem.
10. CE-8. Ability to discuss the validity, scope and relevance of these solutions and be able to present and defend their conclusions.

Transversal:
5. ENTREPRENEURSHIP AND INNOVATION: Being aware of and understanding how companies are organised and the principles that govern their activity, and being able to understand employment regulations and the relationships between planning, industrial and commercial strategies, quality and profit.

6. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

7. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

TEACHING METHODOLOGY

The course will combine both theoretical and practical sessions:
- The theoretical sessions will be devoted to define and explain the rationale of the different problems arising in centralized and market operation of energy systems problems, its formulation as deterministic or stochastic programming problems and the study of the properties of these models.
- During the practical sessions (at least 1/3 of the total course) all the models developed in the theoretical lectures will be implemented using mathematical modelling languages (AMPL/AMPLPy/Pyomo) and used as a computational tool to analyse the properties of the optimal solutions to the energy systems and markets operations.

LEARNING OBJECTIVES OF THE SUBJECT

Students passing this course are expected:

- To be aware of the main characteristics of the countrywide energy production system.
- To know the properties of the different generation technologies (thermal, hydro, wind and photovoltaic plants) and how to formulate the associated optimization models.
- To know an be able to formulate and solve the fundamental problems in the centralised operation of energy systems (Economic Dispatch, Optimal Power Flow, Unit Commitment).
- To understand the structure and rules of the electricity markets (day-ahead, regulation, adjustment, bilateral and futures), and to know the properties and how to compute the equilibrium point (clearing) for some of these markets through the corresponding market clearing mathematical optimisation model.
- To understand the diverse sources of uncertainty in energy systems and markets, how to the represent these uncertainties, together with some measure of risk, through probability scenarios and the appropriate stochastic programming modelisation.
- To understand the characteristics and properties of the different market operation problems (optimal producer's generation bid, optimal consumer's purchase bid, optimal medium-term retailer trading).
- To be able to formulate, to develop the computational implementation and to find the optimal solution of the stochastic programming models for some market operation problem.

STUDY LOAD

Type	Hours	Percentage
Self study	80,0	64.00
Hours large group	30,0	24.00
Hours small group	15,0	12.00

Total learning time: 125 h

CONTENTS

Introduction : centralized vs. market operation of energy systems.

Description:
The wholesale national energy production system.
Countrywide centralized vs. liberalized energy systems.
Electricity markets organization.
Uncertainty in energy systems and markets optimization

Full-or-part-time: 1h 30m
Theory classes: 1h 30m

Optimization of centralized energy systems operations.

Description:
Generation units modeling.
Economic Dispatch
Optimal Power Flow.
Unit Commitment
Solution of cases studies with AMPL/AMPLPy/Pyomo.

Full-or-part-time: 9h
Theory classes: 9h

Market clearing models

Description:
Utility functions, producers and consumers surplus, Social Welfare, market equilibrium conditions.
Single Period Auction model.
Multiple-Period Auction model.
Transmission Constrained Auction models: nodal prices.
Coupling clearing of the european electricity market: EUPHEMIA model.
Solution of case studies with AMPL/AMPLPy/Pyomo.

Full-or-part-time: 9h
Theory classes: 9h

Stochastic Programming in energy optimization.

Description:
Uncertainty in energy systems and markets optimization.
Introduction to stochsatic programming: economic dispatch with stochastic demand.
The Value of the Stochastic Solution.
Risk management.
Probability scenarios generation.
Solution of case studies with AMPL/AMPLPy/Pyomo.

Full-or-part-time: 6h
Theory classes: 6h

Stochastic optimal generation bid models.

Description:
Optimal generation bid for renewable generation units: price-acceptant offer.
Optimal generation bid for thermal generation units: marginal bid curve.
Optimal bid with ramp constraints.
Optimal bid with bilateral contracts.
Solution of case studies with AMPL/AMPLPy/Pyomo.

Full-or-part-time: 9h
Theory classes: 9h

GRADING SYSTEM

The final grade of the course will be based on a series of laboratory assignments where the students will be asked to formulate, implement with AMPL/AMPLPy/Pyomo and analyse some systems and market optimization problems similar to the ones studied during the course.

BIBLIOGRAPHY

Basic:

- Gómez Expósito, Antonio; Conejo, Antonio J.; Cañizares, Claudio. Electric energy systems : analysis and operation [on line]. Boca Raton: CRC Press, 2009 [Consultation: 16/06/2025]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=359945. ISBN 9780849373657.
- Conejo, Antonio J.; Carrión, Miguel; Morales, Juan M. Decision making under uncertainty in electricity markets. Springer, 2010. ISBN 9781441974204.
- Zhu, Jizhong. Optimization of power system operation [on line]. Piscataway, N.J: Wiley-IEEE, 2009 [Consultation: 16/06/2025]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=456286. ISBN 9780470298886.

Complementary:

- Pérez-Arriaga, Ignacio J. Regulation of the power sector [on line]. 2013 [Consultation: 16/06/2025]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-1-4471-5034-3. ISBN 9781447150343.