Title

Optimal scheduling of energy systems: a practical introduction. State-of-the-art modelling techniques and practical examples.

Abstract

Reducing the human carbon footprint encourages the adoption of optimal management strategies in energy systems, aiming for more efficient use of the existing power-producing assets and allowing for deeper integration of renewables.

Energy systems are ubiquitous, from the combined heat and power plants in industrial facilities to net zero energy buildings, which makes them a forefront actor in the transition towards a sustainable society. Today, the use of optimal strategies to manage energy systems of all kinds and sizes becomes even more relevant due to the increasing system complexity (i.e., the number of components), the more diverse services to be offered to the electric grids, and the arising of new market opportunities. In this landscape, devising a nearly optimal strategy based purely on engineering common sense can be challenging because of the multiple and seemingly conflicting choices that must be operated each time. Luckily, the use of automated procedures to systematically find the optimal management strategy is becoming a commercial reality, enabled by the recent developments in digitalisation, automation and forecast techniques.

Although computational resources are becoming increasingly cheap, calculating the optimal management strategy of even straightforward systems can be extraordinarily challenging unless specialised modelling techniques are used. These come with a trade-off here between the model interpretability (i.e., the problem "natural" formulation) and solvability (i.e., the ability to reliably and quickly find the problem optimum). The state-of-the-art optimisation techniques (mixed integer linear programming, MILP) require a linear problem formulation. In contrast, the performance of the system components (Internal combustion engines, turbines, chillers, etc.) is rarely linear with, e.g., the load or operating temperatures. Therefore, several "linearisation" methods have been defined to describe the components accurately and solve the optimisation problems quickly and reliably.

The linearisation techniques are an essential, but not the sole, item in the toolkit of whoever approaches the optimisation of energy systems. For example, other valuable notions include how to model startup cost and minimum load of the system components. These and other practical concepts will be covered in the seminar from both mathematical and software implementation standpoints.

Seminar Agenda

- First lesson (2 h). Time: TBD – Date: TBD (February 2024)
    - Introduction
        - Energy systems promoting energy efficiency and integration of renewables
        - Examples of energy systems and traditional management strategies
        - Practical limitations to the use and effectiveness of optimal management
    - General notions on the optimal management of energy systems
        - Brief references to the concept of optimisation
        - Optimal management of energy systems: problem statement, potential objective functions, optimisation variables, boundary conditions and constraints
        - Selection of optimisation horizon: practical pros and cons, hidden assumptions on the knowledge of future
- Second lesson (2 h). Time: TBD – Date: TBD (February 2024)
    - Optimisation-oriented modelling of energy systems
        - Objective function formulation
        - Modelling of energy fluxes in and out of the system and between the components
        - Modelling of components on-off, minimum loads and mutually exclusive operating modes
        - Linearisation of component performance curves with increasing accuracy and complexity
- Third lesson (2 h). Time: TBD – Date: TBD (February 2024)
    - Practical details of the optimisation problem software implementation
        - Non-exhaustive list of available modelling languages and solvers
    - A Matlab example of practical implementation
        - Problem implementation in MATLAB
        - Comparison between traditional and optimised strategies

Author’s short bio

Guido Francesco Frate received his Bachelor’s and Master’s degrees in Energy Engineering from the University of Pisa (Italy) in 2013 and 2016, respectively, and the PhD from the University of Pisa (Italy) in 2020, with a thesis titled “*Analysis of a pumped thermal electricity storage system with the integration of low-temperature heat sources*”.

From 2020 to 2022, Guido Francesco was a postdoctoral researcher in the Department of Energy, Systems, Territory and Construction Engineering at the University of Pisa, where he became an Assistant Professor at the beginning of 2022. In 2022, Guido Francesco was a *Visiting Researcher* at the Centre for Energy Storage at the University of Birmingham (UK) for three months. In 2023, Guido Francesco was a *Visiting Researcher* at the Laboratory of Applied Thermodynamics at the University of Liege (BE) for three months.

At the University of Pisa, Guido Francesco teaches *Fluid Machines*, *Energy Systems, and Applied Energetics* in graduate and undergraduate engineering courses and has been the co-relator of more than 20 Master’s degree theses.

Guido Francesco’s research focuses on using traditional and innovative energy storage technologies (particularly power-to-heat-to-power and Carnot Batteries) to integrate renewables in energy systems; on the optimal management of energy systems; on the use of high-temperature heat pumps to electrify the process heat production in industry via waste heat upgrading or direct production; finally, on the modelling and simulation of components for innovative energy storage and power-production plants.

Guido Francesco co-authored more than 40 journal and conference papers in collaboration with national and international researchers and industrial partners, presented at several national and international congresses in the EU and USA. He participated in several nationally and internationally funded research projects on energy savings in commercial activities, Innovative power production systems and hybrid electro-thermal energy storage technologies. Finally, Guido Francesco participated in and coordinated several research activities funded by companies to promote energy savings and develop new technologies for more sustainable power production.