



Optimal Control of Hybrid Systems and Renewable Energies

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1. Introduction

International policies for sustainable development have led to an increase in distributed power production based on renewable resources. However, on one side, their intermittency may create problems for the electrical grid, and, on the other side, they are costly.

It is necessary to define new technological solutions that can reduce costs and improve efficiency for energy production from renewables and storage systems that can reduce the intermittent impact of the available resource. Hybrid systems are a viable solution to couple technologies and reduce costs.

Each technology includes its own controller that preserves the health of the system and increases its efficiency. Moreover, usually, each component is integrated into energy management systems that provide reference values for each production plant. In this framework, new control strategies are needed to optimally manage renewable resources and to integrate them in the new energy systems, more and more characterized by the close interaction among different energy vectors and their networks (thermal, electrical, etc.), and by a transition from a centralized structure to a decentralized one (both in terms of sources and controls).

Finally, since new actors (like aggregators, microgrids, energy communities and prosumers) are present in this new energy market, attention should be focused on methods and models able to manage distribute resources for demand response and coordination among different local consumers/prosumers.

The main aim of the Special Issue was to collect papers in the field of the optimal control of power and energy production from renewable resources (wind, PV, biomass, hydrogen, etc.). The specific topics of the Special Issue include (but are not limited to):

- Modelling, optimization and control of production plants from renewables (wind turbines, PV and solar thermal plants, etc.) and hybrid systems;
- Optimization and control of energy systems that include renewables.

The Issue (and the correspondent published book) received several papers, and includes 11 accepted contributions related to the following topics:

- Analysis, modelling and control of production plants from renewables (both single technologies and hybrid systems), with specific reference to PV, solar panels, wind turbines, geothermal plants).
- Energy management systems for buildings, microgrids, and distribution grids that include renewable energies.

2. A Short Review of the Contributions in This Issue

In the following, the papers included in the Special Issue are described, starting from papers that describe the single technology to arrive to hybrid systems, energy management systems, and the optimization of energy systems characterized by several distributed resources over a territory.



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In [1], solar energy systems for cooling are considered, and control approaches are designed to regulate the outlet temperature of the solar collector field, and to choose the operation mode. The overall control problem is a nonlinear optimization problem which involves discrete and continuous variables, and is characterized by a model predictive controller, and a fuzzy algorithm is used to select the adequate operation mode. Wind turbines are instead considered in [2], and particular attention is focused on floating offshore wind turbines (FOWT). A novel optimization methodology, based on the Monte Carlo method, is developed for the manually tuned FOWT feedback controllers to improve the system performance minimizing a cost function. In [3], attention is focused on pumped storage hydro (PSH), which is an effective and economic form of storage that can serve the purpose of capacity for between 4 and 8 h. A dynamic model of ternary pumped storage plant was constructed and compared with that of a conventional plant by integrating them in an IEEE 9 bus test bed system by the use of the MATLAB environment. In [4], attention is focused on the problem of reducing fuel consumption in a diesel generator set (DGS) as part of a wind-diesel power plant (WDPP). A control system for the WDPP is presented that is able to provide an optimal shaft speed of an internal combustion engine (ICE), allowing to reduce fuel consumption by almost 30%. In [5], an optimal control strategy is presented for a fuel cell/battery/supercapacitor light rail vehicle. The control strategy uses the firefly algorithm to optimize the equivalent consumption minimization strategy, and an optimization problem is formalized that minimizes the daily operating cost of the vehicle, which includes the total fuel consumption, initial investment, and cycling costs of power sources. The paper in [6] focuses on railways systems fed in AC, and proposes an innovative power supply system with neutral zones that can improve the eco-friendliness and smart level of an existing architecture, by complementing it with an smart electrical infrastructure based on electrical storage. The proposed solution is based on power electronic devices equipped with energy storage system, connected in parallel to both sides of each neutral zone in the traction substations, power electronic devices connected in parallel to both sides of each neutral zone in section posts, and an energy management system. Both the centralized-control and distributed-control of different functions are allowed via the energy management system. Furthermore, a control algorithm is proposed, based on the modified system for regenerative braking energy utilization, that would increase the efficiency with which all the regenerative braking energy is used in the whole railway electrical system. In [7], a simulator based on a JavaScript engine is proposed, that can be easily interfaced to any SCADA intended for the control and supervision of renewable energy-based generation systems. The proposed tool allows the administrators to easily program various scenarios, sorting out the lack of support found in setting up facilities and the training of novel operator tasks. A use example is also illustrated in the paper, based on three different wind farm generation facility models: one with the essential generation turbine function obtained from the manufacturer curve, another with an empirical model using monotonic splines, and the last one adding the most important operational states. In [8], a hybrid system based on an ultra-capacitor and a lithium-ion battery is developed, such that high power and short-term fluctuations are catered by an ultra-capacitor, whereas long duration and high energy density fluctuations are catered by the lithium-ion battery. A battery energy storage system (BESS) is utilized in parallel to the dc-link capacitor using a buck-boost converter. The hybrid system is modeled, and a control strategy based on a PI controller is developed. The authors in [9] propose the design of a comprehensive inverter-BESS (battery energy storage system) primary control capable of providing satisfactory performances, both in grid-connected and islanded configurations, independently of the number of paralleled generators. In [10], a building automation and energy management system (BEMS) is proposed for a case in which the building uses renewables (geothermal heat pump, solar panels, PV) to satisfy thermal and electrical demands. The developed BEMS includes an equivalent electric circuit model and an optimization tool to optimally manage the HVAC plant, in order to guarantee a desired level of comfort inside rooms. A real test-case is considered and represented by the smart energy building (SEB) located at the Savona

Campus of the University of Genoa, Italy. The management of multiple local systems that include renewables is considered in [11], in which local users are also prosumers that contribute to the reduction of the load asked by the distribution system operator through demand response strategies. A new optimization-based bi-level architecture is proposed for an aggregator of consumers in the balancing market.

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