energies

Editorial

Techniques of Control for Energy Optimization in Actuators, Motors, and Power Generation Systems

Paolo Mercorelli

Institute for Production Technology and Systems (IPTS), Leuphana Universität Lüneburg, 21335 Lüneburg, Germany; paolo.mercorelli@leuphana.de

1. Introduction

It is common sense that an intelligent administration of energy resources represents a unique way to respect the environment and equally redistribute and reutilize resources. In today's energy systems, control and optimization techniques and algorithms play a decisive role. In fact, energy optimization represents a crucial issue in smart-grid/micro-grid energy flow, renewable energy, electrical and hybrid vehicles, as well as in traditional engines, energy storage devices, electrical motors, and in any kind of actuator, including alternative actuators.

In terms of energy, all of these systems, from the biggest to the smallest, play an extremely important role. Any kinds of small motors and actuators (electrical, hydraulic, pneumatic, etc.), which are devoted to the transformation of energy into movement because of their widespread application, should be considered in this process of global, intelligent energy optimization.

This Special Issue of Energies will explore the latest developments in intelligent control algorithms and techniques dedicated to the optimal management of energy in the systems listed above, or in any kind of system in which an algorithm or a technique plays a decisive role in terms of energy optimization and performance. This Special Issue brings together cutting-edge research on advanced control techniques aimed at improving the energy efficiency of actuators, motors, and power generation systems. These technologies are crucial to reducing energy consumption, enhancing system performance, and minimizing environmental impact.

Recent announcements, such as the European Commission's new Green Deal initiatives and updated emissions targets for 2030, underscore the urgency of developing smart energy solutions. Likewise, the U.S. Department of Energy's latest funding round for AI-driven grid optimization tools highlights the growing investment in intelligent systems that enhance energy reliability and efficiency.

The issue covers a diverse range of topics, including, but not limited to, model-based control strategies, adaptive control, smart grid integration, and the application of artificial intelligence in optimizing power output.

By providing insights into both theoretical advancements and practical implementation, this Special Issue aims to offer a comprehensive view of the latest developments in the field. It is intended to foster collaboration among researchers, engineers, and practitioners working towards the common goal of creating more energy-efficient, reliable, and sustainable systems.

Received: 31 May 2025
Accepted: 22 July 2025
Published: 29 July 2025

Citation: Mercorelli, P. Techniques of Control for Energy Optimization in Actuators, Motors, and Power Generation Systems. *Energies* **2025**, *18*, 4036. https://doi.org/10.3390/en18154036

2. Presentation of the Research Papers

Contribution 1 explores a low-cost silver-coated polyamide (PA6) as a thermoresponsive metal-polymer hybrid actuator. PA6's properties are influenced by humidity and water absorption, affecting mass, resistance, and surface morphology. The material's resistance dynamics are modeled using hysteresis, and a switching logic algorithm is introduced to control the actuator force.

In 2, a multi-objective optimization model for large-scale wind power generation planning is proposed, considering power flow, investment costs, and network loss. The improved differential evolution (IDE) algorithm is used to calculate Pareto optimal solutions, ranked by entropy weights and finalized with TOPSIS. The model is tested on China's 2020 power grid, achieving optimized wind power integration.

Contribution 3 proposes a fault-tolerant control (FTC) scheme for a distributed high-speed generator system to maintain operation despite four simultaneous generator faults. The FTC consists of a baseline controller and a lower layer for fault diagnosis, tested through simulations with various actuator faults.

Contribution 4 focuses on a model for wind turbines developed with direct-drive permanent magnet synchronous generators, accounting for active power losses in power system simulations. Analytical assessments and simulations validate the model, emphasizing the importance of active power losses in wind turbine control.

The applicability of tie-line bias control (TBC) in multi-area load frequency control (LFC) systems is re-examined in 5. A new LFC mode is proposed for ring networks where TBC is unsuitable, guiding future LFC designs for complex topologies.

Contribution 6 introduces a new power control scheme for multi-terminal low-frequency AC transmission systems using cycloconverters and virtual synchronous generator (VSG) control. The scheme eliminates the need for communication links for frequency synchronization, and is tested with a two-phase LFAC system.

Contribution 7 shows a hybrid propulsion system to reduce fuel consumption and emissions in off-highway applications. A causal optimization-based power management algorithm is introduced to optimize power split in hybrid powertrains. Simulations show the algorithm's potential to reduce fuel consumption in a diesel multiple-unit train.

In 8, a new fault-tolerant control strategy for a five-phase permanent-magnet vernier (FT-PMV) machine under short-circuit faults is proposed. The strategy minimizes torque ripple and compensates for faults using remedial currents. Simulations and experiments validate its effectiveness.

Contribution 9 defines a method for determining reserve margins in power systems based on short-term reliability of balance. Cost analysis compares this method with conventional approaches, showing greater reliability and efficiency, particularly for wind power generation.

The compound-structure permanent-magnet (CSPM) motor for hybrid electric vehicles (HEVs) is studied in 10. Magnetic coupling and design parameters are optimized using finite element analysis, leading to a proposed decoupling scheme for improved HEV performance.

In 11, a new power system operation model incorporates the output characteristics of wind and solar power generation. The model, tested on China's Northwest power grid, optimizes the integration of large-scale new energy power generation (NEPG).

A feedback linearization controller for a doubly-fed induction generator-based wind turbine is proposed in 12. The controller ensures system stability and track-desired states, and is validated by simulation results.

In Contribution 13, the impact of curtailment on the capacity factors of wind and solar power in Germany's renewable energy system is studied. Simulation results show that curtailment significantly reduces capacity factors, emphasizing the need for enhanced the transmission infrastructure.

In Contribution 14, an adaptive variable-rated sliding mode controller (ASMC) is designed for Bearingless Induction Motors (BIM) to improve performance under large disturbances. Simulations and experiments demonstrate reduced chattering and improved dynamic performance.

In Contribution 15, two optimization frameworks for hybrid vehicle design are compared: nested optimization and enhanced iterative optimization. The iterative approach, applied to a hybrid electric bus, is more computationally efficient and robust compared to varying parameters.

Contribution 16 presents a 3D blade redesign for a five-stage axial compressor using multi-stage CFD methods. The redesign improves stall margin by 13% while maintaining efficiency, which is validated through aerodynamic analysis.

In Contribution 17, a steady-state identification method and optimization scheme for electric variable-pitch propellers in quadrotors are proposed. This method improves endurance and positioning accuracy, and is validated through experimental results.

In 18 a new framework for designing offshore wind farms (OWFs) optimizes layout and electrical infrastructure simultaneously, considering trade-offs like wake losses and collection system length. The framework, applied to the Dutch Borssele area, shows potential for cost savings and more efficient designs.

3. Conclusions

In conclusion, the efficient and intelligent management of energy resources is integral for achieving sustainability and optimizing the performance of modern systems. As we continue to integrate diverse technologies such as smart grids, renewable energy, electric vehicles, and various actuators, the role of advanced control and optimization algorithms becomes increasingly critical. By enhancing energy utilization across a wide spectrum of applications—from small motors to large-scale systems—we can reduce waste, improve efficiency, and foster a more sustainable future. This Special Issue aims to highlight the cutting-edge research and innovations in intelligent energy-efficient systems that benefit both the environment and society. Moreover, it presents a wide variety of research papers that highlight the central importance of energy-related issues in defining control in all possible systems.

Conflicts of Interest: The author declares no conflicts of interest.

List of Contributions

1. Schimmack, M.; Feistauer, E.E.; Amancio-Filho, S.T.; Mercorelli, P. Hysteresis Analysis and Control of a Metal-Polymer Hybrid Soft Actuator. *Energies* **2017**, *10*, 508. https://doi.org/10.3390/en10040508.
2. Li, H.; Li, G.; Liu, S.; Wang, Y.; Wang, Z.; Wang, J.; Zhang, N. Research on Optimal Planning of Access Location and Access Capacity of Large-Scale Integrated Wind Power Plants. *Energies* **2017**, *10*, 442. https://doi.org/10.3390/en10040442.
3. Giger, U.; Kühne, P.; Schulte, H. Fault Tolerant and Optimal Control of Wind Turbines with Distributed High-Speed Generators. *Energies* **2017**, *10*, 149. https://doi.org/10.3390/en10020149.
4. Bonfiglio, A.; Delfino, F.; Invernizzi, M.; Procopio, R. Modeling and Maximum Power Point Tracking Control of Wind Generating Units Equipped with Permanent Magnet Synchronous Generators in Presence of Losses. *Energies* **2017**, *10*, 102. https://doi.org/10.3390/en10010102.
5. Chen, C.; Zhang, K.; Yuan, K.; Teng, X. Tie-Line Bias Control Applicability to Load Frequency Control for Multi-Area Interconnected Power Systems of Complex Topology. *Energies* **2017**, *10*, 78. https://doi.org/10.3390/en10010078.

6. Pichetjamroen, A.; Ise, T. Power Control of Low Frequency AC Transmission Systems Using Cycloconverters with Virtual Synchronous Generator Control. *Energies* **2016**, *10*, 34. https://doi.org/10.3390/en10010034.
7. Schalk, J.; Aschemann, H. A Causal and Real-Time Capable Power Management Algorithm for Off-Highway Hybrid Propulsion Systems. *Energies* **2016**, *10*, 10. https://doi.org/10.3390/en10010010.
8. Gu, C.; Zhao, W.; Zhang, B. Simplified Minimum Copper Loss Remedial Control of a Five-Phase Fault-Tolerant Permanent-Magnet Vernier Machine under Short-Circuit Fault. *Energies* **2016**, *9*, 860. https://doi.org/10.3390/en9110860.
9. Kwon, K.b.; Park, H.; Lyu, J.K.; Park, J.K. Cost Analysis Method for Estimating Dynamic Reserve Considering Uncertainties in Supply and Demand. *Energies* **2016**, *9*, 845. https://doi.org/10.3390/en9100845.
10. Xu, Q.; Sun, J.; Luo, L.; Cui, S.; Zhang, Q. A Study on Magnetic Decoupling of Compound-Structure Permanent-Magnet Motor for HEVs Application. *Energies* **2016**, *9*, 819. https://doi.org/10.3390/en9100819.
11. Li, H.; Li, G.; Wu, Y.; Wang, Z.; Wang, J. Operation Modeling of Power Systems Integrated with Large-Scale New Energy Power Sources. *Energies* **2016**, *9*, 810. https://doi.org/10.3390/en9100810.
12. Alrifai, M.; Zribi, M.; Rayan, M. Feedback Linearization Controller for a Wind Energy Power System. *Energies* **2016**, *9*, 771. https://doi.org/10.3390/en9100771.
13. Kies, A.; Schyska, B.; Von Bremen, L. Curtailment in a Highly Renewable Power System and Its Effect on Capacity Factors. *Energies* **2016**, *9*, 510. https://doi.org/10.3390/en9070510.
14. Yang, Z.; Wan, L.; Sun, X.; Li, F.; Chen, L. Sliding Mode Variable Structure Control of a Bearingless Induction Motor Based on a Novel Reaching Law. *Energies* **2016**, *9*, 452. https://doi.org/10.3390/en9060452.
15. Zhuang, W.; Zhang, X.; Peng, H.; Wang, L. Simultaneous Optimization of Topology and Component Sizes for Double Planetary Gear Hybrid Powertrains. *Energies* **2016**, *9*, 411. https://doi.org/10.3390/en9060411.
16. Ning, T.; Gu, C.W.; Ni, W.D.; Li, X.T.; Liu, T.Q. Aerodynamic Analysis and Three-Dimensional Redesign of a Multi-Stage Axial Flow Compressor. *Energies* **2016**, *9*, 296. https://doi.org/10.3390/en9040296.
17. Sheng, S.; Sun, C. Control and Optimization of a Variable-Pitch Quadrotor with Minimum Power Consumption. *Energies* **2016**, *9*, 232. https://doi.org/10.3390/en9040232.
18. Rodrigues, S.; Restrepo, C.; Katsouris, G.; Teixeira Pinto, R.; Soleimanzadeh, M.; Bosman, P.; Bauer, P. A Multi-Objective Optimization Framework for Offshore Wind Farm Layouts and Electric Infrastructures. *Energies* **2016**, *9*, 216. https://doi.org/10.3390/en9030216.