Open Invited Track - 2025 IFAC Workshop on Smart Energy Systems for Efficient and Sustainable Smart Grids and Smart Cities (SENSYS 2025)

Advanced Methods for Sustainable Energy and Mobility Integration

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Abstract

Modern energy systems are transforming to address sustainability and efficiency challenges, particularly in reducing greenhouse gas (GHG) emissions. Transportation, as a major contributor, has driven the adoption of electric vehicles (EVs) and alternative fuels like biofuels and hydrogen. These developments demand innovative frameworks integrating energy and mobility systems. However, many challenges persist: achieving optimal management requires advanced control strategies, including model predictive, distributed, and hierarchical control, alongside scheduling methods for resource allocation. Machine learning (ML) techniques play a critical role in addressing these challenges, offering data-driven solutions for optimizing energy generation, distribution, and consumption. The goal of this open invited track is highlighting the potential of advanced control approaches and ML-driven optimization to enhance the efficiency, resilience, and sustainability of interconnected energy and transportation systems, supporting the transition to cleaner energy solutions.

Detailed Description:

The landscape of modern energy systems has evolved significantly in response to the imperative for sustainability and efficiency. The necessity to reduce greenhouse gas (GHG) emissions has prompted the implementation of cleaner and more efficient technologies across a range of sectors, particularly energy systems and transportation. Road transport continues to represent a significant source of global GHG emissions, urging the widespread adoption of electric vehicles (EVs) and the extensive use of alternative energy sources such as biofuels and hydrogen. These developments require a comprehensive redesign of supply chains and the formulation of innovative planning frameworks. The interconnected networks of energy, transportation, and communication systems form a complex ecosystem that necessitates unified management to guarantee reliability and efficiency. Indeed, the common elements of electricity, hydrogen and biofuels provide a foundation for meeting both energy and transportation needs. These interconnections underscore the critical role of collaborative management across multiple sectors, highlighting the need for robust frameworks. If properly coordinated, these networks enable dynamic, real-time adjustments to external disturbances and evolving demands, enhancing their resilience and sustainability. Nevertheless, significant

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challenges remain, including grid instability due to distributed loads, inefficiencies in charging operations, and poor utilization of charging infrastructure. Furthermore, there is a need for proper management of the enormous amount of data relevant to these complex systems.

Nevertheless, the intrinsic flexibility and adaptability of these interconnected systems allow dynamic responses to numerous challenges. This versatility is crucial for the effective management of the intermittent characteristic of renewable energy sources and the accommodation of evolving consumer needs. Given the importance of these systems in the modern framework, the central goal is the achievement of optimal control and management tools. This involves the development and implementation of advanced control strategies, including model predictive control, distributed control, and hierarchical control approaches. The optimal management of these systems also comprehends the development of energy generation, distribution, and consumption strategies with the objective of maximizing system efficiency. Key aspects include scheduling methodologies for the optimal timing and allocation of energy resources, as well as leveraging machine learning (ML) techniques to enable data-driven operations. Given the vast quantities of data involved, ML holds significant promise for addressing challenges and optimizing performance across these interconnected systems.

This Open Invited Track is conceived to be a crucial point for the comprehensive exploration of new advancements in the study of these integrated networks, emphasizing both practical applications and methodological developments, the track seeks to address the multifaceted challenges and opportunities.

The main contributions will be related to:

- Machine learning techniques for data-driven optimization in energy systems and sustainable mobility.
- Integration of electric vehicles, hydrogen, and biofuel systems into smart grids.
- Optimal location and operation strategies for charging infrastructure.
- Model predictive control for the coordination of energy and transportation systems.
- Advanced scheduling methodologies for energy resource allocation and demand response.
- Distributed and hierarchical control strategies for interconnected energy networks.
- Energy-efficient routing, path planning, and navigation in sustainable mobility applications.
- Demand forecasting and adaptive management for renewable energy variability.
- Electrification strategies for public transportation, and urban logistics.
- Applications of AI and machine learning for predictive maintenance in energy systems.
- Coupling smart grids with mobility systems to enhance resilience and flexibility.
- Real-world case studies of integrated energy and mobility systems in urban and rural settings.
- Modeling and analysis of uncertainties in energy demand, supply, and infrastructure resilience.

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