frontiers | Frontiers in Energy Research

TYPE Editorial
PUBLISHED 28 November 2022
DOI 10.3389/fenrg.2022.1086523

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Smart Grids, a section of the journal Frontiers in Energy Research

RECEIVED 01 November 2022
ACCEPTED 11 November 2022
PUBLISHED 28 November 2022

CITATION
Wang H, Ye Y, Chen Y, Chen Y, Yang Q, Cui Q and You P (2022), Editorial: AI, data analytics, and mechanism design for DER integration toward net zero.
Front. Energy Res. 10:1086523.
doi: 10.3389/fenrg.2022.1086523

Editorial: AI, data analytics, and mechanism design for DER integration toward net zero

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KEYWORDS

net zero, energy transition, smart grid, distributed energy resources (DER), artificial intelligence, data analytics, optimization

Editorial on the Research Topic
AI, data analytics, and mechanism design for DER integration toward net zero

1 Introduction

The energy system is undergoing a fundamental energy transition by integrating low-carbon distributed energy resources (DERs) in distribution networks to accelerate net zero. The increased DER uptake poses significant challenges in operating energy systems to achieve net zero with high reliability and low cost. In particular, the inherent variability of renewable generation, such as solar photovoltaic systems, brings significant uncertainties to the energy system, causing reliability concerns. DERs also cause power quality issues, such as voltage fluctuations. But the distribution system was not designed to support large bidirectional power flow and host a high uptake of DERs. The existing economic mechanism, which worked in the past, cannot provide effective economic signals to manage DERs in the grid. How to effectively integrate DERs and harness their flexibility has become one of the most challenging problems in the energy sector.

AI, optimization, and mechanism design have become promising tools to address the aforementioned challenges in the DER integration toward net zero. For example, AI and advanced optimization can improve the efficiency and effectiveness of system operations with a high uptake of DERs by scheduling energy storage and dispatching DERs in real-time. Mechanism design can contribute to market-based or price-based solutions to manage DERs for higher reliability and lower costs.

This collected articles in Research Topic "*AI, Data Analytics, and Mechanism Design for DER Integration Toward Net Zero*" provide a glimpse into the state of the art in AI, optimization, and mechanism design for DER integration. These articles address several key research problems, including hosting capacity, economic dispatch, and the reliability assessment in distribution networks, for a path toward net zero.

This Research Topic contains four articles. Two articles focus on hosting capacity maximization of renewable generation and security-constrained dispatch in distribution networks with high penetration of renewables, respectively. The other two articles focus on low-carbon economic dispatch and reliability assessment of integrated energy systems (IES), respectively.

Ye et al. studied the hosting capacity problem from a market viewpoint. It presented that falling electricity prices resulting from increasing renewables penetration jeopardize investment cost recovery and integration of renewables. A bi-level optimization problem was formulated, where the upper-level problem aims to maximize the hosting capacity of renewables, and the lower-level problem describes the market clearing process considering network constraints. Case studies demonstrated the validity and significance of the proposed method and generated interesting insights.

Cui et al. aimed to utilize the flexibility in distribution networks to lower carbon emission without compromising the accessibility of reliable electricity. A security constrained dispatch policy based on safe reinforcement learning was proposed. A case study performed on a modified version of the IEEE 33-bus system validated the effectiveness of the proposed method in decarbonization. The guide for the development of distribution networks was provided for dispatching DERs in an economical and eco-friendly way.

Wu et al. studied economic mechanisms in an electricity-heat-cooling-gas integrated energy system for energy conservation and emission reduction. Considering carbon emissions levels of the system, a carbon emission unit cost model with a dynamic reward and penalty pricing mechanism is proposed. An optimal dispatch model was presented to minimize the operation cost. The proposed method limits the carbon emissions of the system by penalizing high-carbon emission systems and rewarding low-carbon emission systems, facilitating carbon neutrality.

Zhu et al. presented a reliability assessment of an integrated energy system with rich flexibility of gas–thermal slow dynamic characteristics. It studied the importance of different key equipment nodes for the long-term stable and reliable operation of the integrated energy system. It showed that the gas-thermal inertia could reduce the amount and frequency of load shedding, alleviate the system operation risk, reduce the system operation cost, and improve the system's long-term operating reliability.

Our goal in putting together this Research Topic is to provide a glance at the wide variety of aspects, spanning from technical modeling and assessment to market-based solutions enabling energy transition towards net zero by integrating DERs. We are also aware that the four papers selected are a small fraction of works focusing on DER integration. We hope that these articles will succeed in attracting readers for further research on this significant Research Topic of smart grids.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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