frontiers | Frontiers in Energy Research

TYPE Editorial
PUBLISHED 10 July 2024
DOI 10.3389/fenrg.2024.1447772

OPEN ACCESS

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RECEIVED 12 June 2024
ACCEPTED 21 June 2024
PUBLISHED 10 July 2024

CITATION
Zhang C, Zhou Y, Su X, Wang B and Yan Z (2024), Editorial: Advanced operation and control of distributed and grid-scale energy storage in modern low-voltage power systems.
Front. Energy Res. 12:1447772.
doi: 10.3389/fenrg.2024.1447772

Editorial: Advanced operation and control of distributed and grid-scale energy storage in modern low-voltage power systems

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KEYWORDS

energy storage system, distributed generation, distribution network, low-voltage power system, microgrid, virtual energy storage

Editorial on the Research Topic
Advanced operation and control of distributed and grid-scale energy storage in modern low-voltage power systems

1 Introduction

In the context of zero-emission energy transition, modern low-voltage power systems, including distribution networks (DNs), microgrids and smart buildings, are witnessing a significant increase in renewable distributed generation (DG) systems such as rooftop photovoltaics and small-scale wind turbines. However, the fluctuating and intermittent characteristics of renewable power as well as uncertain loads can cause voltage Research Topic, three-phase unbalance and impaired power quality, posing significant challenges to the operation and control of low-voltage power systems. Energy storage is an emerging technology that can address these challenges, helping enhance system stability, operating reliability, control flexibility, and cost-effectiveness.

This Research Topic aims to present the advanced operation and control methods of distributed and grid-scale energy storage in modern low-voltage power systems. Eight research articles are accepted on this Research Topic, and they can be classified into three categories, i.e., Optimal allocation of energy storage systems (ESSs) in low-voltage power systems, Coordinated operation and control of energy storage systems with other resources, and Virtual energy storage (VES) via aggregating various flexible energy resources.

2 Optimal allocation of energy storage systems in low-voltage power systems

To increase the utilizsation efficiency of renewable energy and achieve an economic operation, Zhang et al. propose a stochastic optimal allocation method for locating and sizing battery energy storage systems (BESSs) in DNs. In this work, firstly a rainflow counting method with linearization means is applied to model the degradation of BESSs. Then, a stochastic optimization method is adopted to address the uncertainties of renewable DG and load. Furthermore, a solution algorithm based on a feasibility pump algorithm is introduced to fast solve the BESS allocation problem which contains a large number of integer variables. Finally, through comparative analyses on a 33-bus DN system, the results show that the proposed method achieves the optimal performance in terms of operational safety and economic efficiency.

Public buildings have large energy consumption and contribute to a high level of carbon emission. With the PV installations and the random charging behavior of electric vehicles, a configuration method of both single-phase and three-phase ESSs is proposed by Li et al., to address a local PV consumption Research Topic and provide three-phase unbalance management. Firstly, an improved affinity propagation clustering algorithm based on a spatial weighted matrix distance is used to obtain the typical scenarios of PV outputs and loads. Then, a bilevel configuration model of single-phase and three-phase ESSs is developed. The upper level optimizes the ESS capacity to achieve the minimum ESS life cycle cost, while the lower level coordinates commutation switches and ESSs to realize economic operation. The numerical results present the validity and rationality of the proposed clustering algorithm and ESS configuration method.

Considering the active islanding operation of DNs, Jiahao et al. propose a united credible capacity evaluation method for energy storage and DG. The method integrates day-ahead economic scheduling in a normal state and islanding during a fault to obtain accurate reliability calculation. The optimal islanding scheme in the fault state is obtained by solving a network partitioning problem and an optimal islanding correction problem alternately. Then, the convergence criterion based on variance coefficient rather than manual selection is designed for the reliability calculation. Finally, the trusted capacity of DG with energy storage is evaluated in a PG&E 69-bus system. The case study shows that at 20%, 30% and 40% storage configurations, the trusted capacity is increased by 23%, 53% and 61%, respectively, indicating that the integration of energy storage has a significant impact on the trusted capacity of DG.

3 Coordinated operation and control of energy storage systems with other resources

The ESSs are often coordinated with other controllable devices in a DN. In the work of Ding et al., a multi-timescale voltage control model is introduced to address the operational challenges posed by renewable DG installed in DNs. An ESS is integrated into a soft open point, forming an energy storage equipped soft open point (E-SOP). Based on the different response time, day-ahead network reconfiguration scheduling, interday optimization of droop control functions of the E-SOPs and PVs, and real-time local voltage droop control are systematically coordinated to address voltage Research Topic and reduce network power losses. Considering the time coupling of energy storage operation and uncertainties, the state of charge (SoC) intervals and the droop control functions are optimized for the E-SOP and PV real-time operation. The optimized SoC intervals with the droop control functions allow energy storage to dynamically adjust the charging or discharging power in the real-time stage, and promote the efficient operation of E-SOP throughout the whole day. With comparative analyses on a 33-bus DN system, the effectiveness of the proposed method is verified.

The work of Zhang et al. develops a bilevel optimization model for siting and sizing static transfer switches (STSs) in rural DNs. The combined PVs and ESSs operate with STSs to reduce the three-phase unbalance of a DN. The upper-level model minimizes the investment and maintenance costs of STSs, while the lower-level model minimizes the three-phase unbalance for the daily operation. To efficiently solve this bilevel problem, a hyperparameter alternating iteration method is developed to iteratively solve the planning and operation models. Finally, a case study of a three-phase power distribution system modified from the IEEE 13-bus system is carried out. The results show that the proposed bilevel optimization model can effectively alleviate the three-phase unbalance in a rural DN and reduce the STS planning cost.

4 Virtual energy storage via aggregating various flexible energy resources

There are abundant flexible energy resources being integrated into modern commercial smart buildings. Electricity prices for tenants in a commercial building are generally determined by a subcontracting power supplier (SPS), and thus the tenants are lack of incentive to participate in DR. Huang et al. propose a dynamic pricing approach based on Stackelberg games between the SPS and tenants to regulate energy consumption of the tenants for DR participation. Meanwhile, by optimizing the operation of flexible energy resources such as air conditioning systems and electric vehicles in the public area, a VES model of a commercial building is established, such that the building SPS can repond to DR signals. The proposed pricing method and VES model are tested based on a real commercial building scenario to demonstrate the validity of the game theory pricing method and verify the role of VES in the DR of buildings.

A two-layer optimization approach for electric-hydrogen integrated energy systems (IESs) to promote multi-energy complementarity is proposed by Zhang et al. The integration of demand response (DR) resources is considered as VES to enhance the IES operation. The upper layer determines the optimal capacity of IES equipment by minimizing the daily operating costs as well as carbon emissions. By contrast, the

lower layer optimizes the day-ahead and intraday dispatch of IES equipment and VES. The results show that the electric-hydrogen IES can not only improve the utilization efficiency of renewable energy, but also reduce the use of fossil energy and thus carbon emissions.

In addition, Ren et al. propose a virtual power plant (VPP) scheduling model based on multi-objective information gap decision theory (IGDT) considering a function of vehicle-to-grid, which aims to minimize the system operating cost and carbon emission. Renewable DG, ESSs, electric vehicles, etc., are the main energy resources for a VPP. The weight and evasion coefficients are applied to describe the uncertainties of renewable DG power and load demand at different levels. Accordingly, a robust optimization model of IGDT and an advanced solution algorithm are introduced for the VPP scheduling problem. The solution results show that the method can effectively realize the peak shaving and valley filling of the demand, and has advantages in economy, environmental benefit, robustness and stability.

5 Conclusion

In summary, the economical and safe operation of low-voltage power systems with a high proportion of renewable DG and new loads remains a major challenge. The contents of this Research Topic can provide valuable insights into the low-voltage power system planning and operation with ESSs.

Author contributions

CZ: Writing–original draft, Writing–review and editing. YZ: Writing–review and editing. XS: Writing–review and editing. BW: Writing–original draft. ZY: Writing–review and editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This work was supported in part by Australian Research Council under Grant DE240100059, the National Natural Science Foundation of China under Grant 52307091, the Natural Science Foundation of Jiangsu Province under Grant BK20230952, and the China Post-doctoral Science Foundation under Grant 2023M740976.

Conflict of interest

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The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

The handling editor ZD declared a past collaboration with the author(s) CZ, XS, BW.

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