Advances in Reliability, Safety and Security

ESREL 2024
Collection of Extended Abstracts

An Economical And Reliable Energy Sharing And Storage Model For Multi-Microgrid Systems

Xiaoling Song, Na Pei

Department of Management Science and Engineering, Nanjing University of Science and Technology, Nanjing, China

Keywords: shared energy storage, multi-microgrid, multi-objective optimization, reliability, optimized configuration

In the development of a new energy system that heavily relies on renewable sources, the Microgrid (MG) has emerged as a feasible and sustainable solution for promoting the widespread adoption of renewable energy in grid-connected consumption (Rodriguez et al., 2024). However, the isolated MG's capacity and ability to withstand disturbances are limited (Cao et al., 2022). To tackle this issue, the Multi-Microgrid (MMG) system has been introduced (Masrur et al., 2024). The fluctuating, decentralized, and intermittent nature of loads and new energy outputs within each MG can significantly impact power system operations (Dong et al., 2023). Energy storage (ES) technology can effectively address the spatial and temporal imbalances between stochastic power generation and power demand in MGs (Das et al., 2018). However, challenges persist in terms of the complexity of customizing energy storage capacity, the limited efficiency of energy storage utilization, and the absence of a defined profit model for investing in energy storage facilities when independently investing in energy storage for microgrids (Zhang et al., 2021). The emergence of the "sharing economy" model provides a new solution to manage energy storage in MMG (Bian et al., 2024). By implementing a centralized energy storage sharing system, each microgrid is furnished with distributed energy storage (DES) of a specific capacity. This setup not only enhances the economic efficiency of the MMG system through inter-network power assistance but also provides backup capacity for microgrids during emergencies, thereby enhancing the reliability of MMG operations.

This paper presents an economical and reliable energy storage and sharing model for MMG systems. The proposed framework involves a shared energy storage (SES) system that operates under the principle of centralized sharing and decentralized reuse, as depicted in Figure 1. In this system, the SES is managed and utilized by MMGs with the aim of minimizing overall investment and operational costs. The SES operator coordinates the charging and discharging requirements of the MGs, coordinates investment plans for energy storage facilities, and manages charging and discharging schedules. The centralized energy storage facility offers charging and discharging services to each participating MG through the distribution grid, while distributed energy storage units engage in energy storage sharing through inter-grid power assistance. Additionally, the distributed energy storage units support the backup needs of their respective MGs for isolated operation during emergencies, thereby enhancing the operational reliability of each MG.

Furthermore, a two-layer allocation model is created for the MMG system with an aim of multi-objective optimization. The planning layer model is designed to optimize the system's annual economy and reliability, and then provides the configuration scheme to the operation layer model. The operation layer model, on the other hand, is focused on minimizing the daily operating cost of the system to achieve optimal operation. Meanwhile, the operation layer communicates the system's operating costs, carbon emissions, and critical load support coefficients for each typical day to the planning layer, which are used as the foundation for calculating the planning objectives. It then evaluates the profit contribution of each MG to the SES system using the Shapley value method, which helps in deciding how to allocate the initial investment cost of the SES system among different users.

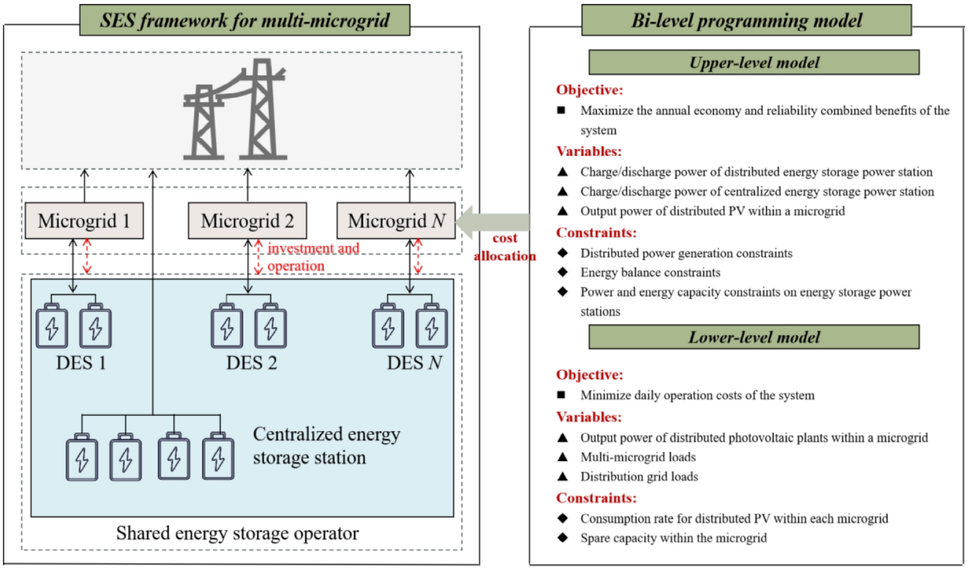

Figure 1. Framework of energy sharing and storage for multi-microgrid systems

The proposed economical and reliable energy sharing and storage model for multi-microgrid systems have the potential to enhance the utilization of energy storage and effectively balance the economic and reliability aspects of the energy storage allocation scheme. Future studies could explore integrating distributed network technologies like blockchain with shared energy storage to optimize the operation of multi-microgrid systems.

Acknowledgements

The paper presents the results of the work granted by Polish Safety and Reliability Association.

References

Bian, Y., Xie, L., Ye, J., Ma, L., Cui, C. 2024. Peer-to-peer energy sharing model considering multi-objective optimal allocation of shared energy storage in a multi-microgrid system. Energy 288, 129864.

Cao, W., Xiao, J., Cui, S., Liu, X. 2023. An efficient and economical storage and energy sharing model for multiple multi-energy microgrids. Energy 244, 123124.

Das, C., Bass, O., Kothapalli, G., Mahmoud, T., Habibi, D. 2018. Overview of energy storage systems in distribution networks: Placement, sizing, operation, and power quality. Renwwable & Sustainable Energy Reviews 91, 1205-1230.

Dong, Y., Zhang, H., Ma, P., Wang, C., Zhou, X. 2023. A hybrid robust-interval optimization approach for integrated energy systems planning under uncertainties. Energy 274, 127267.

Masrur, H., Khaloie, H., Al-Awami, A., Ferik, S., Senjyu, T. 2024. Cost-aware modeling and operation of interconnected multi-energy microgrids considering environmental and resilience impact. Applied Energy 356, 122320.

Rodriguez, M., Arcos-Aviles, D., Guinjoan, F. 2024. Simple fuzzy logic-based energy management for power exchange in isolated multi-microgrid systems: A case study in a remote community in the Amazon region of Ecuador. Applied Energy 357, 122522.

Zhang, N., Jiang, H., Li, Y. 2021. Aggregating distributed energy storage: cloud-based flexibility services from China. IEEE Power and Energy Magazine 19(4), 63-73.