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GUEST EDITORIAL

Integration and control of grid-scale battery energy storage systems: challenges and opportunities

1 | INTRODUCTION

The current energy storage system technologies are undergoing a historic transformation to become more sustainable and dynamic. Beyond the traditional applications of battery energy storage systems (BESSs), they have also emerged as a promising solution for some major operational and planning challenges of modern power systems and microgrids, for example, enabling the integration of renewable energy sources by reducing their intermittency and improving the voltage, frequency, and reliability profiles of power grids. In other words, energy arbitrage, increased capacity of renewable energy resources, deferred investment in power grid components, reduced congestions, reduced carbon footprint, reduced losses, and stability stress the importance of conducting extensive and ground-breaking research and experimentation in the area of BESSs. This effort will maximize the benefits of using existing and novel BESS technologies in power systems. However, the success in the use of BESSs is driven by many technological developments and cost reductions. The current special issue enables a unique, dedicated opportunity to disseminate state-of-the-art research works in innovative aspects of BESSs from the technology and system points of view.

2 | ARTICLES IN THE SPECIAL ISSUE

In this special issue, twenty-two articles have been received, all of which underwent peer review. Of the twenty-two originally submitted articles, seven have been accepted and the rest have been "rejected," that is, they did not meet the IET Renewable Power Generation journal criteria for publication. Thus, the overall submissions were of high quality, which marks the success of this special issue. A brief presentation of each of the articles in this special issue follows:

In [1], the use of a multi-port DC/DC power converter-based BESS as a multi-functional device in improving the transient stability and enhancing the power transmission capacity of high voltage direct current (HVDC) grids is analyzed. The presented control structure is an effective control framework that deals with multi-port DC/DC power converters to achieve DC voltage control and eliminate voltage and power oscillations. Also, the control scheme of the DC/DC converter can control the power flow in the intended transmission line. Analysis and time-domain simulations of the system demonstrate that the presented method gives the system an appropriate and acceptable damping improvement. The presented method simultaneously improves the transient stability of DC voltage and controls power oscillation damping within HVDC grids using BESS.

In [2], a construction method of lithium-ion batteries' thermoelectric coupling model based on digital twin for the problems of long simulation time and low accuracy in existing models is presented. In this regard, the digital twin structure system of lithium-ion batteries is analyzed, and then the thermoelectric coupling model of the batteries is constructed on the digital twin platform ANSYS TwinBuilder by considering the coupling effects of the thermodynamic model and the equivalent circuit model. Based on ANSYS TwinBuilder, the order of the thermodynamic model is reduced, and then the simulation time is reduced to the second level, which improves the simulation efficiency and meets the real-time simulation requirements of the digital twin. Furthermore, considering that the operating parameters of lithium-ion batteries are variable, the parameters of the equivalent circuit model are identified online based on the variable forgetting factor recursive least squares algorithm, which updates the parameters of the model and improves the simulation accuracy. Finally, the efficiency and accuracy of the model are verified through simulation analysis.

In [3], a bi-level model of the energy storage system (ESS) planning for renewable energy consumption by considering the boundarization of power flow constraint is presented. To solve the non-convex problem in the power flow equations, a boundarization method with the integration of power flow constraint is incorporated into the bi-level optimization model, which can reflect the influence of power flow constraint on the operation state and charging-discharging power of ESS. Based on the model's solving results, the operational risk index of ESS is presented to achieve the optimal installation location of ESS. Through the analysis of the case study, it is concluded that the upper and lower bound curves of ESS charging and discharging power for different scenarios subject to constraints, such as power flow limit and voltage range, can be obtained by using the presented boundarization method. In addition, the operation risk evaluation index of ESS at different potential nodes can be calculated after the operation simulation. It can be used to evaluate different siting schemes and provide suggestions for the reasonable layout of ESS. Furthermore, the comparison between the presented bi-level model and the single-level model indicates that the presented method, which considers the interaction between ESS planning and operation, can decrease load shedding and improve the consumption proportion of renewable energy.

In [4], a planned hybrid system's ideal configuration and component sizing are put into practice over a 25-year period. The presented hybrid system includes an inverter that makes it easier to transfer electrically generated energy to users, as well as PV, wind turbine (WT), fuel cell (FC), a water electrolyzer, and a tank of hydrogen gas. The complex optimization problem posed by the presented system is addressed and the best optimal values for the subsystems that make up the entire system are discovered using a novel artificial rabbits optimization (ARO) technique. To assess and confirm the presented ARO's efficacy and applicability in resolving the considered optimization problem, statistical tests are conducted. In comparison to existing optimization algorithms, the presented ARO algorithm demonstrated its adequacy for solving the optimization problem under consideration. Future complex and non-linear engineering issues can be resolved by the presented ARO.

In [5], the investment strategy for photovoltaic (PV) panels and battery storage to attain the net-zero energy house (ZEH) status within a regional power system comprising a manager and multiple users is explored. It is demonstrated through a case study in Jono, Kitakyushu, that incorporating battery storage into the power system effectively reduces power imbalances and enhances energy utilization efficiency, which is crucial for attaining ZEH objectives. Furthermore, the analysis of the two presented scenarios reveals their potential to decrease annual electricity costs significantly. Additionally, the importance of implementing a proper sharing policy to incentivize individual users to share electricity while preventing the excessive exploitation of communal resources is highlighted.

In [6], an optimal frequency response coordinated control strategy for hybrid wind-storage power plants, grounded in state reconstruction, is presented to enhance the frequency support capabilities and power generation efficiency of wind power and ESSs. This strategy delves deeply into the nuances of virtual inertia and primary frequency regulation. It is noted that the rapid frequency regulation capacity of a hybrid wind-storage power plant is contingent upon the operational statuses of both wind turbines and energy storage systems. The strategy presented harmonizes the grid's active power reserve requirements with the state reconstruction of the wind-storage system, employing adaptive control parameters in response to increases or decreases in system frequency. The distinct methodologies for virtual inertia and primary frequency regulation are advocated. Specifically, an adaptive virtual inertia control strategy is crafted distinctly for wind turbines and ESSs, hinging on state reconstruction to bolster the speed of frequency response. Moreover, primary frequency regulation is orchestrated through the coordinated control of wind turbines and energy storage, ensuring economical operation and sustained active power support. The efficacy and applicability of the presented frequency response coordinated control strategy are well-established. Overall, this article aims to (1) address practical challenges by applying the presented frequency response coordinated control strategy in engineering contexts where wind turbines and energy storage operate in unison, and (2) explore a plethora of innovative control algorithms for wind turbines and ESSs, specifically tailored for frequency response control.

In [7], the stability of both frequency and voltage is improved by optimal sitting, sizing, and setting of control parameters of BESS in a low-inertia grid with different penetration levels of renewable energy. A network based on Kundur's four-machine system is modeled for the first study, and two of the four synchronous generators are replaced with wind farms. Then, the production of the third synchronous generator is decreased by 13%. According to the results, the addition of wind farms causes the frequency drop below 49.6 Hz for more than 5 min, indicating instability. It is also demonstrated that with optimal control parameters and placement, a 60 MW BESS can alleviate the voltage and frequency fluctuations, leading to enhanced stability. This method is tested on the IEEE 39-bus network, where the installation of a BESS with a capacity of 9 MVA could restore the frequency stability.

3 | SUMMARY

This special issue reports state-of-the-art research studies of interest to an audience with a background in grid-scale BESS.

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