An improved charging/discharging strategy of lithium batteries considering depreciation cost in day-ahead microgrid scheduling

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Abstract

An energy storage system is critical for the safe and stable operation of a microgrid (MG) and has a promising prospect in future power systems. Economical and safe operation of storage systems is of great significance to MGs. This paper presents an improved management strategy for lithium battery storage by establishing a battery depreciation cost model and employing a practical charging/discharging strategy. Firstly, experimental data of lithium battery cycle lives, which are functions of the depth of discharge, are investigated and synthesized. A quantitative depreciation cost model is put forward for lithium batteries from the perspective of cycle life. Secondly, a practical charging/discharging strategy is applied to the lithium battery management in MGs. Then, an optimal scheduling model is developed to minimize MG operational cost including battery depreciation cost. Finally, numerical tests are conducted on a typical grid-connected MG. Results show that the depth of discharge of storage is scheduled more rationally, and operational cost is simultaneously saved for MG under the proposed management strategy. This study helps to improve the cost efficiency and alleviate the aging process for lithium batteries.

Keywords:
Battery depreciation cost
Charging/discharging strategy
Energy storage system
Microgrid
Optimal scheduling

1. Introduction

Microgrid is a promising form to integrate distributed generators (DGs), including wind turbines (WT) and photovoltaic (PV), which plays an important role in dealing with the energy crisis, the environmental degradation, and the power shortage problems [1]. Due to the characteristics of intermittency and uncertainty, the integration of WT and PV into MGs brings great challenges to the scheduling and operation. In order to alleviate the power fluctuation of the renewable energy, MGs are generally equipped with an energy storage system (ESS), which not only contributes to maintain the safe and stable operation of MG, but also plays a role in load shifting [2,3].

Compared to the conventional grid, one of critical issues in MG is the storage management. An energy management system is necessary in MG for the coordination of various DGs, ESS and even the load. Several methods have been reported focusing on the MG energy management with the objective of minimizing the operation cost and environmental impact [4–8]. The heuristic control strategy is one of common methods used for ESS charging/discharging control in MGs [4,5]. Decisions are made based on the current information, which is particularly appropriate for real-time dispatch. In [6], an optimization model based on Mesh Adaptive Direct Search is established for MG energy management. A fuzzy logic expert system combined with linear programming is proposed for battery scheduling in [7]. The framework can cope with uncertainties in MG. The battery depth of discharge (DOD) can be scheduled at a convenient degree by the fuzzy logic technology. In [8], a probabilistic approach for MG operation management is proposed under the uncertain environment. In the objective function, the operation cost of storage device is included. Similar to the cost model of a controllable generator, the storage cost is composed of bid price and start-up/shut-down cost, which still has room for improvement.

With respect to ESS economical operation, research has been carried out in [9–14]. In [9], a two-layer management approach is proposed for day-ahead economical scheduling and real-time dispatch. In the model, ESS cost consists of the charging/discharging cost and the cost related to the cycle life loss. However, the cycle life of a battery depends closely on the DOD, charging strategy, and so on [10,11]. In [12], a penalty cost as a function of storage DOD is added to MG operational cost. It acts as a soft constraint to prevent a large DOD of the storage. A more reasonable cost model is given on the basis of the decline in state of health (SOH) of ESS in [13]. The SOH directly affects the ESS lifetime.© 2015 Elsevier Ltd. All rights reserved.
However, the relationship between ESS lifetime and the DOD is not exactly depicted by these models. Accordingly, this problem is investigated in this paper to improve the management of ESS. The operation, maintenance and depreciation costs of ESS are considered for its economical management. A battery cycle life model is proposed, based on which the depreciation cost in each charging/discharging cycle is modeled as a function of DOD. Then, an optimal scheduling model is developed to minimize MG total operating cost based on the expressions of the cycle life and the corresponding depreciation cost function.

The framework of MG generation scheduling is briefly introduced firstly. In general, MG day-ahead scheduling is to develop generation schemes with minimum operational cost based on the forecasting of load demand and renewable energy (e.g. PV, WT) [16]. This paper focuses on the charging/discharging management for EB storage in day-ahead MG scheduling. The proposed architecture of the MG optimal scheduling model is shown in Fig. 1.

2. Architecture of the proposed MG optimal scheduling model

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