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Combining frequency containment reserves and renewable power leveling in energy storage systems

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Abstract

The objective of this paper was to show that a combination of renewable energy sources with energy storage systems, which provide frequency containment reserves FCR (also called primary frequency control), improves the performance of both systems. This double benefit comes out in a reduction of intraday trading for the storage system and a leveled power injection of the renewables.

Considering the regulations that apply for battery storage systems to provide FCR in Germany, interaction with other units is essential to guarantee availability of the system. This interaction is usually performed market based by intraday trading or by flexible power generation or consumption combined with the storage system. This paper, however, showed the benefits of interaction with fluctuating renewable energy sources.

Energy storages and renewables were clustered to a common grid connection point to utilize the fluctuations of the renewable power generation directly for battery management. Simulation results based on sample photovoltaic and wind profiles showed the double benefit of the configuration. Intraday trading was reduced by 33% up to 57%. At the same time, fluctuations decreased, so the renewable power injection better matched a predefined power schedule.

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1. Introduction

Electricity balancing services like frequency containment reserves FCR (also known as primary frequency control) are essential for a safe operation of the power system. Up to now this service is usually provided by conventional power plants. However, the increasing penetration of renewable energy sources (RES) and the reduction of conventional power plants require new concepts and providers for those system services.

Several approaches have been presented in literature, for example FCR provision by wind turbines and photovoltaic plants [1], but this concept requires permanent curtailment of renewable energy in order to provide positive FCR. Instead, battery energy storage systems (BESS) seem to be more promising, but feasibility strongly depends on the regulations.

While FCR in France [2] and in Denmark [3] is organized in short time intervals and separately for upwards or downwards regulation, FCR in Germany has to be provided in both directions and for the period of one week. To account for these high requirements, the German TSOs published guidelines to organize and facilitate BESS operation for FCR [4], [5].

One of the basic concepts is the interaction of the BESS with other units in the power system, which is inevitable to maintain permanent availability despite limited capacity. This interaction can either be realized market based by intraday trading (IDT), which means changing power schedules of other units abiding by defined lead times [6], [7]. However, this service can be quite expensive depending on the flexibilities available in the power system.

The second way of interaction with other units is to utilize the flexibilities regarding their own power schedules. In [8], a flexible industrial load provides SOC (state of charge) management, which for example means the BESS can be charged by reducing the load compared to its actual power schedule. Similarly, [9] and [10] propose a combination of BESS with thermal power plants.

This paper deals with a BESS that provides FCR combined with fluctuating RES. So in comparison to the approaches presented above, the power available for SOC-management is random and cannot be influenced. It will be shown, that this concept offers a double benefit. It improves SOC-management for FCR and contributes to RES power leveling at the same time.

The paper is organized as follows. Section 2 presents the regulations that apply to BESS in order to provide FCR in Germany, especially in terms of SOC limits and operating range. Section 3 deals with the proposed combination of RES and BESS to provide FCR and RES power leveling, the renewable power profiles applied for simulation and the operation strategy for the BESS. In section 4 simulation results are presented for different storage capacities and renewable power combinations which prove the benefits of the proposed system in terms of SOC-management and RES leveling.

Nomenclature

RES	renewable energy sources
PV	photovoltaic
WT	wind turbine
BESS	battery energy storage system
SOC	state of charge
FCR	frequency containment reserves
IDT	intraday trading
OF	overfulfilment
DB	dead band control

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