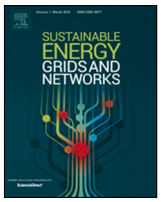
Sustainable Energy, Grids and Networks 32 (2022) 100854

Contents lists available at ScienceDirect

Sustainable Energy, Grids and Networks

journal homepage: www.elsevier.com/locate/segan



Battery energy storage integration in wind farms: Economic viability in the Spanish market

E. Lobato *, L. Sigrist, A. Ortega, A. González, J.M. Fernández

Universidad Pontificia Comillas (IIT-ICAI), Alberto Aguilera 25, 28045, Madrid, Spain

ARTICLE INFO

Article history:
Received 5 October 2021
Received in revised form 23 May 2022
Accepted 7 July 2022
Available online 16 July 2022

Keywords:
Battery energy storage systems
Flexibility
Renewable integration

ABSTRACT

This paper proposes an economic assessment tool that determines the viability of a battery energy storage system (BESS) integrated within renewable power plants for different market applications such as day-ahead price arbitrage, participation in the balancing market and schedule tracking by reducing wind deviations. In particular, maximum BESS investment prices are derived to make BESS potentially viable for each functionality. A case study of an actual 30 MW wind farm participating in the Spanish electricity market is used to test the economic viability of different sizes of Li-ion and vanadium-redox BESS. Results show that with the actual structure and level prices in Spain, the participation in the balancing market could achieve positive internal rates of return, and the combination of additional market functionalities does not improve substantially BESS viability.

1. Introduction

1.1. Motivation

Energy storage systems (ESS) is considered a strategic technology aiming at increasing the penetration of renewable energy sources (RES) [1]. Among the different energy storage possibilities (water-pumping reversible hydro plants, batteries, compressed air energy storage, hydrogen and others) [2], battery energy systems (BESS) are arguably the most promising ones, with a special focus on the integration of BESS within renewable power plants for different market purposes [3]. Integration of BESS within renewable power plants has been proposed for different market purposes such as (i) day-ahead price arbitrage, (ii) reserve provision for frequency control services or (iii) generation schedule tracking to avoid economic penalizations of wind deviations.

From the technical point of view, the services that BESSs can provide to the grid have been widely recognized. These include, for instance, reduction of wind power fluctuations [4,5], generation schedule tracking [6–8] or frequency response services [9,10]. However, the complexity in evaluating the economic viability of BESS within power systems is one of the main barriers in defining a feasible business model [11]. Although experiencing a gradual and significant reduction, current BESS cost structures [12,13] still rarely make them economically attractive when providing a single market service. It has been argued that different technologies of storage could be an economically viable flexibility option if they can participate in multiple market places (both energy and reserve markets) with the possibility of aggregation of benefits [14]. Due to the limited energy capacity of BESS, assessing the economic viability of integrating BESS within wind farms requires the simulation of optimal operation during selected timeframes (e.g., weeks) to derive total expected maximum benefit along the lifetime of the BESS

One issue often missed in the literature is that BESS frequent charge–discharge cycling accelerates depreciation due to degradation effects. This is especially significant when providing frequency control services since the BESS must react to constant up and down setpoints sent by the control systems [15]. Thus, it is essential to introduce formulations that model degradation and reduce unproductive charging or discharging commands within optimization models. Unproductive commands are those that create low benefits (both technical and economic) and as such, better be avoided to contain degradation.

To provide a comprehensive evaluation of the economic viability of BESSs integrated with wind farms participating in several energy and ancillary service markets while considering BESS degradation is the objective of this paper.

1.2. Literature review

The economic viability of a particular BESS for a specific market service depends on the structure, regulation and price levels of the system under study, and in this way results for a particular country cannot be extrapolated to a different system. Valuable economic assessments of storage in specific systems can be found within literature such as Monte Carlo simulation is

* Corresponding author.
E-mail address: Enrique.Lobato@iit.comillas.edu (E. Lobato).

https://doi.org/10.1016/j.segan.2022.100854
2352-4677/