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ScienceDirect

Energy Procedia 99 (2016) 137 – 146

Energy Procedia

10th International Renewable Energy Storage Conference, IRES 2016, 15-17 March 2016, Düsseldorf, Germany

Optimal Dispatch Scheduling of a Wind-Battery-System in German Power Market

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Abstract

Due to the principle of supply and demand, the real-time electricity price in the German spot market varies throughout a single day. Since wind power is non-controllable and partially unpredictable, it is difficult to schedule its power output. Suppliers lose profits by not taking full advantage of the price variation. Moreover, the forecast errors can represent a financial risk, in case of the provision of reserve energy. In this paper, an approach is presented where a battery energy storage system (BESS) is used to make wind power plants (WPPs) scheduled. First, the BESS is used to adjust the dispatch plan of wind power output, in order to exploit price variations beneficially in day-ahead and intraday markets. Second, the BESS is applied to address forecast errors during the real-time operation, in order to balance particularly the expensive forecast errors, which can endanger the stability of the power system. Deviations between forecast and real power output are characterized as expensive forecast errors, if the payment for the deviations is more than 50 €/MWh. In order to realize a multiuse of the battery, a genetic algorithm is employed to optimize the portion of power and energy capacity for the BESS, which participates in above-mentioned different energy market auctions. In contrast, for the daily operation strategy of the BESS, an hourly-discretized linear optimization algorithm is employed. The wind power forecasts for a pool of wind farms with an overall nominal power of 238 MW are generated with WEPROG's (WEPROG GmbH, Wetter & Energie PROGnosen, Böblingen, Germany, http://www.weprog.com/.) multi-scheme ensemble prediction system (MSEPS). In addition, the measured data of the wind farm pool were also available. Time-series data of electricity prices for the German/Austrian area are taken from EEX European Energy Exchange AG, Leipzig, Germany, https://www.eex.com/de/. and used partially for the optimization and verification. The results show that, by applying the proposed method, financial benefits are achieved for the wind farm and the cost caused by forecast errors can be decreased.

Peer-review under responsibility of EUROSOLAR - The European Association for Renewable Energy

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Peer-review under responsibility of EUROSOLAR - The European Association for Renewable Energy
doi:10.1016/j.egypro.2016.10.105

Keywords: dispatch scheduling; wind power forecast error; battery energy storage system; German energy market

1. Introduction

The renewable energy sector in Germany has been booming during the last decade. Especially the penetration of wind generators reached a level where almost 10 % of the yearly electricity demand can be covered by wind energy. For the marketing of wind power, it can be in principle divided into two different business models, namely fixed feed-in tariff model and direct marketing model. The fixed feed-in tariff model means that generated wind power is financially supported by a fixed tariff, which was originally an incentive to stimulate more investment into renewable energy industries. The direct marketing model means that generated wind energy is sold by private balance responsible parties (BRP) directly to the energy market, so that the wind energy is equally treated with the conventional energy at the same market price.

Direct marketing means higher expenses for independent power producers (IPPs), because the wind power has to be forecasted and the forecast errors will cause cost for balancing energy from TSOs. However, the dynamic electricity price in different energy markets gives also the incentive to develop an optimal trading strategy, which can benefit from the negative electricity prices and price variations. Considering the difficulty of direct marketing for wind power due to its fluctuation, battery storage energy systems can provide the flexibility to exploit the price variations and avoid the cost of balancing energy. Many storage technologies for example Li-ion batteries are constantly improving and becoming attractive for medium scale stationary energy storage applications. Due to the fast response time, there are no obstacles from a technical point of view preventing batteries from modifying the dispatch plan for WPPs immediately. The big challenge is currently still the cost which allows for the economic viability of the investment in BESS. Therefore, a variety of research focuses on business models allowing for economic operation of BESS considering different maturity levels and profit potentials.

In [3] the possible applications for BESS to support WPPs from technical and economical perspectives are summarized. Three main applications have been paid close attention to in this study: (1) deployment of primary control power, (2) balance of forecast errors and (3) improvement of direct marketing. The ability of BESS to fulfill the requirements to provide different types of control power has already been proven by some studies such as [4], [5] and [6] describe the possibility of BESS to provide primary control power for different country cases. [7] found that a wind farm with the capacity of 100 MW needs a BESS with the power and capacity of 34 MW/ 40 MWh for the maximum forecast errors of ±4 %. [8] and [9] discuss how to improve the direct marketing of wind power with the support of BESS as an optimization application to save costs and increase income.

Nomenclature

BESS	battery energy storage system
BRP	balance responsible parties
EEX	European Energy Exchange
IPPs	independent power producers
MSEPS	multi-scheme ensemble prediction system
TSO	transmission system operator
WPPs	wind power plants (WPPs)

2. Metheodology

2.1. German energy market

The European Energy Exchange (EEX) is a spot market for power. It operates day-ahead energy market and intraday energy market. The day-ahead market is organized by an auction process and closed on 12:00 p.m. one day before the physical delivery day. The intraday market is organized by continuous trading. The intraday market opens