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Cost-Benefit Analysis of Battery Storage System for Voltage Compliance in Distribution Grids with High Distributed Generation

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Abstract

The increasing distributed generation of renewable energies in distribution networks leads to several challenges for distribution network operators (DNOs). During high feed-in times, voltage violations can occur if the hosting capacity of the grid for distributed generation is exceeded. The paper at hand investigates the installation of grid-supporting battery storage system (BSS) in the medium voltage (MV) level to serve mainly for voltage compliance and to defer grid reinforcement. A control approach for the BSS based on two characteristic curves is suggested. The BSS is then analyzed technically and economically for scenarios of high distributed generation. The results show that the alternative of BSS has potential to defer grid reinforcement in the presented case studies. However, the power curtailment is more viable than the BSS and grid reinforcement. The economic viability of BSS can increase in the future based on the expected reduction of battery costs. Furthermore, BSS have the technical potential for providing other services, since voltage violations occur during high feed-in times.

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Keywords: Grid-Supporting Storage, Battery Storage System, Grid Reinforcement, Voltage Compliance;

1. Introduction

The energy transition to renewable energy leads to substantial changes in the generation structure from large power plants to numerous small distributed generators (DGs). The increasing distributed generation of fluctuating

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renewable energy sources in distribution grids imposes several challenges for the distribution network operators [1]. If the penetration level of DGs exceeds the hosting capacity of the grid, the voltage at some critical nodes can violate the voltage tolerance band defined in EN 50160. To mitigate voltage violation problems, DNOs can undertake grid reinforcement measures, such as installing new lines or transformers. For the case of Germany, the dena study estimates grid reinforcement costs for the distribution system of approximately 27.5 billion € until the year 2030 [2]. Therefore, other alternatives should be investigated technically and economically, aiming for reducing the grid costs in future scenarios. In addition, flexibility options for the grid operation, such as battery systems, have to be investigated in order to successfully proceed with the German energy transition.

Battery systems have been discussed in several studies as an alternative to grid reinforcements [3, 4]. In addition, numerous studies focus on the grid integration of photovoltaic (PV) systems in the low voltage (LV) network level to support the voltage compliance. The focus on the LV level is pointed out in [5]–[9], while the medium voltage has only been in focus of few case studies, such as [10]. Some relevant studies and their results in relation to this paper are presented in Table 1.

Table 1. Overvirew on studies for grid storages in Germany

Ref	Investigations related to distribution grids	Findings	Comparison with this paper
[3]	Economic potential for battery systems to avoid grid reinforcement in the LV and MV level. Constant cosφ is considered for the DGs	Battery systems are economically viable in LV but not in MV level compared to grid reinforcements	- Sizing of battery systems is based on storing the power exceeding a defined limit - Control strategy for battery systems is not investigated - Battery losses are not considered
[14]	Evaluation of a grid-supporting BSS as a mobile asset compared to grid reinforcement in a real MV grid	BSS (25 kW, 1 MWh, lithium-ion) is a profitable option and technically viable	- The sizing of BSS is based on yearly simulations - The battery system's control is performing peak shaving
[4]	Economic potential of battery systems to avoid overloading in the MV and LV level compared to grid reinforcement	Battery systems are not economical at present prices compared to other alternatives (e.g., feed-in curtailment).	- Sizing of battery systems is based on storing the power exceeding the line capacity limit - Control strategy for battery systems is not investigated
[15]	Economic potential of different alternatives incl. battery systems compared to grid reinforcement in typical LV networks	The voltage supporting BSS can be viable for some networks	- A voltage dependent control of the battery systems is assumed - The examples are only for the LV level

Furthermore, an optimized planning for the installation of battery systems to support the grid is presented in [11]. Moreover, the voltage compliance can be supported by several strategies of reactive power (Q) provision by the DGs, as discussed in [12]. Besides, the installation of large BSS in Germany (larger than 1 MWh) is increasing since 2014. The use case for the installed battery storage systems so far is mainly the participation in control power markets [13].

In the literature, there is no comprehensive evaluation of battery systems compared to other grid reinforcement solutions at the MV level. Especially, a fair sizing approach is missing which indicates the trade-offs of designing a battery storage system to avoid grid reinforcements. Furthermore, the combination between local integration strategies of DGs, such as reactive power provision and BSS needs to be thoroughly investigated to derive a comparable benchmark.

Hence, this paper investigates the utilization of grid-supporting BSS in MV level to serve mainly for voltage compliance and to avoid grid reinforcement. A control approach for the BSS is developed. Grid-supporting BSS are then analyzed technically and economically compared to grid reinforcement. The costs are assessed from the perspective of DNOs in high distributed generation scenarios. The paper ends with a discussion of the competiveness of BSS as an option to avoid grid reinforcement.