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Cost assessment of storage options in a region with a high share of network congestions

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ABSTRACT

In Germany's federal state of Schleswig–Holstein (S–H) the installed capacity of distributed electricity generation from renewable energy sources has been growing faster than the transmission capability of the distribution and transmission networks. Currently, this causes network congestions and requires corrective measures such as curtailment. Hence, around 3.5% of renewable production in S–H was curtailed in 2012. As one potential option for reducing these yield losses, energy storage has been suggested. Costs of different storage technologies used for this purpose are investigated in this paper. Detailed empirical data from recent years is used to assess the characteristics of curtailment actions. The analysis shows that storage's cycling intensity is low while the power intensity is potentially high on the distribution grid level. From a transmission grid perspective, congestions are analysed studying the residual load exepected in a 2025 scenario in combination with current and future capacities to and from S–H. The results suggest that considerable amounts of surplus situations for a potential utilisation by energy storage only occur with current transfer capacities and diminish with the planned transmission grid expansion. By looking at the cost assessment results on both the distribution and transmission grid level, it is obvious that solely utilising current and 2025 levels of curtailed energy does not allow the cost recovery for any of the considered storage technologies. Hence, additional storage capacity in S–H for reducing curtailment losses is only viable if complementary use cases can be found or parts of the investment costs can be socialised or if the costs of storage technologies drop significantly.

1. Introduction

1.1. Congestion situations in S–H

With increasing shares of renewable sources providing electricity (RES-E) in the power system, many regions in Germany are facing challenges to keep up the pace of increasing transmission capacity of its distribution and transmission networks. This circumstance causes network congestions requiring corrective and operational measures in order to avoid overloading network assets. Recently, curtailment of distributed generation is experienced more often. Depending on the region, system operators apply curtailment requests as often as a thousand times per year. In Germany, a total of 550 GWh or 0.4% of the production from RES-E was curtailed in 2013 [1–3].

Naturally, curtailment entails yield losses and curtailment volumes should be as small as possible, both from a plant operator's as well as a societal perspective. As one alternative option, energy storage connected to distribution networks has been suggested for reducing these yield losses. In times of high RES-E generation, energy storage allows surplus electricity causing congestions to be stored. Later, when the congested network situation relaxes, the stored electricity can be released and transmitted to the customers.

The northern German federal state Schleswig–Holstein (S–H) represents a region with a high share of RES-E, in terms of its energy balance nearly 100% by 2014. In comparison with the total share of RES-E of about 27% in Germany, effects of a high penetration can be observed much earlier in Schleswig–Holstein. Therefore, in 2014 around 60% of Germany's curtailed energy was

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located in Schleswig–Holstein. Between 2 and 8% of the RES-E in this region was curtailed. The curtailment was caused mainly by congestions in the 110 kV distribution system. Since 2011 the importance of congestions in the transmission system is increasing [3–5,34].

For this particular region, we have assessed the characteristics of network congestions during the last years with a high resolution of empirical data in dimensions of space and time [6]. Based on this analysis we evaluated the application and the costs of energy storage systems in order to reduce the yield losses of RES-E in the period until 2022 for the distribution network and until 2025 for the transmission network in S–H.

1.2. Description of transmission and distribution network in S–H

The power system in S–H is characterized by three major network operators which are allocated in different voltage levels:

- TenneT TSO GmbH (>110 kV),
- E.ON Netz GmbH (110 kV) and
- Schleswig–Holstein Netz AG (<110 kV).

In S–H the total installed capacity of RES-E is 5.2 GW (end of 2012 according to [7]), which represents about 7% of the installed capacity in Germany. In 2013, 80% of the total renewable generation capacity in Schleswig–Holstein was connected to the distribution grid of the Schleswig–Holstein Netz AG (S–H Netz AG). Due to the high share of wind power in their network and in conjunction with a wind farm's unit size, around 80% of the distributed generation is connected to the medium voltage level [7]. Fig. 1 gives an overview of the corresponding RES-E allocation in S–H.

As a consequence of network congestions, the three listed major network operators frequently take congestion management actions. Predominantly, S–H Netz AG curtails the distributed power units, because most units are connected to their network. The majority of curtailment is linked to wind power units [3,8,9].

A current study [5] predicts further, significant growth of RES-E, especially for wind power in S–H and the local government estimates [13] that the installed capacity of wind energy will reach 9 GW by 2020. In addition, more than 2 GW of offshore wind will be connected to the transmission grid by 2020. Due to the combination of the rapid development of RES-E and the delays in grid extension [3], enduring network congestions can be expected in the coming years.

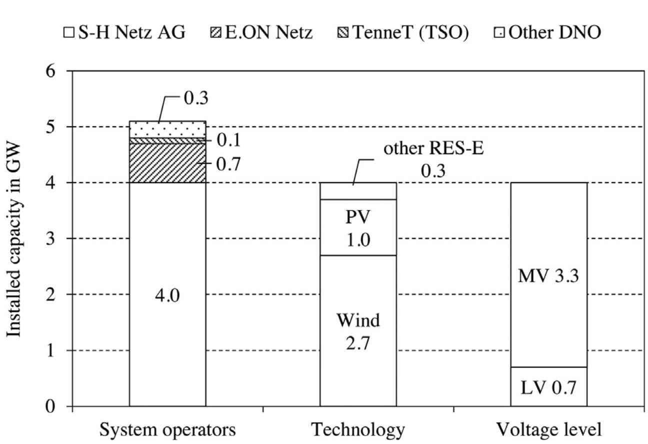

Fig. 1. Overview of the RES-E shares and their low (LV) and medium voltage (MV) connection in Schleswig–Holstein in 2012 based on [7].

Based on the detailed analysis in [6], we present an overview of the analysis and results in the following structure: Section 2 describes the methodology applied to assess congestion situations for energy storage on different grid levels. Results are presented and discussed in both Section 3 and 4. While in section 2 we describe and analyse the classification in temporary and permanent network congestions on the distribution grid level, section 4 identifies surplus situations on the transmission grid level for a 2025 scenario and subsequently assesses storage costs. Section 5 draws the general conclusions regarding the potential use of energy storage in S–H.

2. Methodology

In this section the generic approach used to assess the benefits of energy storage by reducing number of congestion management actions that need to be taken is presented. In general, the analysis is separated according to the examined system levels, the distribution (Section 3) and the transmission grid level (Section 4).

2.1. Focus and limitations

Following the description of the current situation in S–H, major challenges in the power system arise from congestions, where currents exceed the power line limits. The purpose of this paper is to illustrate the relevance of energy storage as a solution to address these congestions on a regional scope, ensuring sufficient results for the transmission system in S–H and the 110 kV distribution system. Hence, the hereby investigated application purpose of energy storage technologies is the utilisation of otherwise curtailed energy resulting from temporary or permanent congestion situations in the distribution and transmission grid. The interaction of storage applications with other local system parameters, such as voltage and short circuit behaviour, or global system parameters, such as frequency, is not part of the analysis. Further studies addressing these specific issues can for instance be found in Refs. [32,33].

2.2. Distribution system

For the analysis on the distribution grid level, three main steps are identified: (1) network congestions are classified in regards to possible energy storage applications; (2) operational requirements for energy storage are characterised in order to define the specific use case; (3) economic benefits of energy storage are assessed. As input for our analysis, we prepared the following data sets which are based on publicly available data:

- The Ecofys-curtailment database, which consists of all published congestion management actions by the German system operators between 2009 and 2013. All records are standardised and linked to affected distributed power units and substations [9,10],
- Empirical energy data of S–H Netz AG, including residual load, feed-in, losses, etc. The records have a time resolution of 15 min and are allocated to a specific voltage level [11],
- Geographical data of the network development plan of S–H Netz AG, including appropriate wind areas, areas of wind parks, substations, lines, estimated regions of congestion management actions, etc. [12].

2.2.1. Classification

As illustrated in Fig. 2, network congestions in the distribution system can be basically categorized into two types which lead to different strategies for employing energy storage.