Direct marketing of wind generation in Burgenland with the support of battery storage systems

Thomas Nacht, Martina Weissenbacher and Johannes Paeck

Kurzfassung

Direkte Vermarktung der Windkrafterzeugung im Burgenland mit Unterstützung durch Batteriespeichersysteme

Die Förderung von erneuerbaren Energieträgern führte mitunter zu einem starken Ausbau der Windkraft in Österreich. Da aktuell die ersten Windkraftanlagen nach einer Laufzeit von 13 Jahren keine Förderung mehr erhalten, ist es notwendig neue Geschäftsmodelle für diese Anlagen zu finden. Die Entwicklung und Validierung eben dieser Geschäftsmodelle ist das Ziel des Projektes Windvermarktung.

Die große Herausforderung bei der Vermarktung von Windenergie ergibt sich aus dem volatilen Charakter der Windkrafterzeugung, mit dem ein Prognosebedarf einhergeht, der Unsicherheiten unterliegt. Bei dem in diesem Artikel diskutierten Ansatz zur direkten Vermarktung der Windkraft am liberalisierten Strommarkt, äußert sich die Prognoseunsicherheit in zusätzlichen Kosten durch Ausgleichsenergie.

Eine Untersuchung unterschiedlicher Direktvermarktungsstrategien soll aufzeigen, ob diese wirtschaftlich sind (Netzparität) und darlegen, inwieweit sich die Wirtschaftlichkeit durch den Einsatz von Li-Ionen Batteriespeichern aufwerten lässt. Die Verwendung von Batteriespeichern ist mit hohen Investitionskosten verbunden. Um die Wirtschaftlichkeit zu garantieren, müssen neue Einsatzstrategien für diese Speicher entwickelt werden.

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The funding of renewable energies led to an increasing number of wind turbines in Austria. After a duration of 13 years, funding is expiring for the first of these wind turbines. This calls for the development and investigation of new business models for wind generation, which is the goal of the research project Windvermarktung.

The main challenge of marketing this commodity lies in the volatile character of wind generation. This volatility requires forecasts to be made, which leads in uncertainties. In this article, the approach of direct marketing of wind energy at the liberalised electricity market is discussed. At the liberalised market the uncertainties of the of the forecasts result in additional costs for balancing energy.

Analysing different direct marketing approaches will illustrate, if economic feasibility (grid parity) can be reached and if the profitability of wind direct marketing can be increased by adding a Li-Ion battery storage system. Four different storage deployment strategies are developed and their economic effects analysed to see if the high investment costs for battery storage systems can be reimbursed.

Introduction

The EU's goal to increase the share of renewables in energy consumption to 20 % by 2020 [1] in combination with the availability of new technologies lead to the transition of the energy system commonly known as Energiewende. To promote renewable energies, funding started in Austria by 1994 [2]. But it was not until 2002 that the installed capacity of wind and PV started increasing, where an amendment of the Ökostromgesetz came into effect. Through this amendment operators were offered funded tariffs for the renewable energy generated. With the profitability of the generation capacities secured, major investments in wind and PV followed. In Austria wind generation capacities were installed mostly in the counties of Lower Austria (1,411.5 MW) and Burgenland (997.2 MW) [3], due to the preferable wind situation.

Since according to the Ökostromgesetz the period of tariff funding for wind power expires after 13 years of operation, the funding for several plants has already stopped or is going to expire in near future.

To further ensure the economic operation of the wind power plants not eligible for funding and provide incentives for further investments, new approaches need to be developed. One opportunity is to participate in the liberalised electricity market, after the funding has expired. This approach has two main challenges resulting from the volatile character of wind generation: (1) The merit order effect of high penetration of RES on the energy markets [4], which will get increasingly more important as more RES will participate on the liberalised market. A geographic dispersal of the generation capacities can mitigate the merit order effect, as not all generation capacities operate at full power all the time [5]. (2) The volatility of wind generation [6] which leads to the necessity of using forecasts to predict the generation [7]. As predictions themselves show uncertainties, deviations between the energy sold (as predicted) and the actual energy generation can occur, resulting in balancing power [8].

The Energie Burgenland, after installing a total capacity of 507 MW of wind power over the last 20 years [9], is confronted with the challenges and problems described above. Starting in 2016, the funded tariffs for the first wind power plants have expired, leading to the necessity of implementing new business models. Solving this problem is the key goal of the research project Windvermarktung. This project is funded by the Klima- und Energiefonds as part of the programme "Vorzeigeregion Energie 1. Ausschreibung". To ensure the profitability of wind power generation, the Energie Burgenland considered different marketing strategies, with the main focus on participating at the liberalised market. This approach requires an analysation of different marketing concepts. To be able to compensate the uncertainty of wind generation, the use of flexibilities needs to be considered. In this case the flexibility will be provided by a Li-Ion battery storage system.

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Direct marketing of wind generation at the liberalised market

To optimise the profitability of the wind generation, two different approaches are investigated. Direct marketing on the liberalised market is assumed for these approaches, one of which represents the current strategy of wind marketing of the Energie Burgenland. In a next step, to further optimise the profitability, the usage of battery storages system (BSS) in combination with different deployment strategies is discussed.

The basis for this analysation is data provided by the Energy Burgenland for the duration of July 2016 to January 2017. Even though this is a rather short period of time to make an elaborate statement, it should be enough, to draw general conclusions about the situation and to develop methods, which can be used as soon as more data is available. The data provided show a resolution of 15 minutes and include:

- wind generation forecasts at different times,
- the amount of energy traded at the day-ahead market and the intraday market, as well as
- the actual generation and
- the corresponding prices for the markets as well as the first clearing prices [8] for the balancing energy.

As the total installed capacity considered in this data is constantly increasing, as more wind power plants stop to receive funding, the data was scaled down to one wind turbine with an installed capacity of 3 MW, representing an Enercon E-101 [10]. Consistently the results of the research and the findings can be scaled up again to the required installed capacity of the wind generation currently without funding. There is a strong correlation between the generation of all the plants in the data pool, because of the close proximity of wind generators to each other and the geographical conditions in Burgenland. As a consequence, this approach of up- and downscaling is feasible.

The first marketing strategy only considers the day-ahead market and the corresponding forecast (day-ahead strategy). Gate closure for day-ahead market is at 12 o'clock on the day before delivery of the energy, which leaves a lot of room for deviations between forecast and actual generation. The second strategy (day-ahead and intraday strategy) considers trading at both the day-ahead and intraday market, thus giving the opportunity to adapt the traded amounts of energy to a more up-to-date forecast. The lead time for the intraday market is up to 30 minutes before delivery of the energy [11]. The second strategy, while being more complex should lead to a reduction in balancing energy and thus increasing the profitability. The intraday market can be used to sell additional amounts of energy, if the forecast predicts more generation in comparison to the day-ahead forecast. Consequently, if the forecast predicts less generation, the missing amounts of energy can be bought at the intraday market. The corresponding market prices dictate the income and costs. Finally, the costs for balancing energy are calculated by comparing the total energy traded with the actual generation and the corresponding balancing energy prices.

To further increase the profitability of wind generation a BSS is introduced. For the deployment strategies of the BSS different approaches can be chosen. Diac [12] chooses a broad scope of different storage technologies and parameters to make a benefit analysation for wind energy integration. The conclusion is drawn, that most crucial factors for the profitable combination of wind generation and storages systems are the energy price spread, the round efficiency and the investment costs of the storage system. Díaz-Gonzales et. al. [13] state, that using a storage system for shifting the time when wind generation is sold on the market is, under the given conditions, not feasible without funding as the investment costs are too high. Another strategy for the usage of a BSS in combination with wind generation was discussed in Miettinen et. al. [14], where the approach to use a storage system to compensate balancing energy costs is investigated for the Nordic energy market. The conclusion of this research is, that balancing energy compensation show no economic feasibility.

Storage deployment strategies to increase the value of wind generation

Building on these approaches and findings, new storage deployment strategies are developed with regards to the situation in Austria and Burgenland in specific. Four different deployment strategies to further increase the profitability of wind generation by using a BSS were considered. To evaluate these strategies simulation models for optimization have been developed. The BSS considered for the research is a Li-Ion battery storage with an installed capacity of 2 MW, a usable capacity of 2.7 MWh, a round efficiency of 87 % and investment costs of approximately 60 €/kWh [15].The parameters are being changed in accordance to Table 1 in order to make a sensitivity analysis. The total investment costs are on basis of the data for the 2 MW, 2.7 MWh storage, with an assumed distribution between power to capacity costs of 40 % to 60 %.

The storage deployment strategies (Figure 1) differ, when it comes to the decision when the charging and discharging takes places. To improve the profitability of marketing wind energy, the deployment strategies for the BSS set the focus on either reducing the costs for balancing energy or improving the times (price dependent) when wind generation is sold. The following four deployment strategies are considered:

Tab. 1. BSS parameters for the sensitivity analysis of the different storage deployment strategies, own calculation on basis of [15].

Maximum electrical power [MW]	Maximum capacity [MWh]	Assumed investment costs [€]
1	1.35	793,800
1	2.70	1,270,080
2	1.35	1,111,320
2	2.70	1,587,600
2	5.40	2,540,160
4	2.70	2,222,640
4	5.40	2,540,160

- *Balancing energy compensation (Strategy I):*
  The BSS is used to store energy when positive balancing energy situations (actual generation exceeds the traded energy amounts) occur and the positive balancing energy reaches a predefined threshold. The BSS is discharged when a negative balancing energy situation (actual generation is lower than the traded energy amounts) occurs and reaches a predefined threshold. These thresholds are defined by the costs and incomes for positive and negative balancing energy.
- *Positive Balancing Energy compensation (Strategy II):*
  For this strategy negative balancing energy is neglected. The rules for charging the BSS stay the same, but the energy in the BSS is sold the next day at the day-ahead market. For selling the energy, the hours with the highest predicted prices are chosen, which should lead to the best economic results.
- *Negative Balancing Energy Compensation (Strategy III):*
  This strategy neglects the positive balancing energy and only considers a compensation of negative balancing energy. The necessary amounts of energy for the compensation are acquired at the day ahead market. For the acquisition of the necessary energy only situations with the lowest prices are considered, planning the charging times is dependent on price forecasts for the corresponding market. The basic goal is to fully charge the BSS once a day and discharge it, whenever the negative balancing power reaches the predefined threshold.
- *Arbitrage and balancing energy trade (Strategy IV):*
  The final discussed strategy sets focus on day-ahead and intraday market prices

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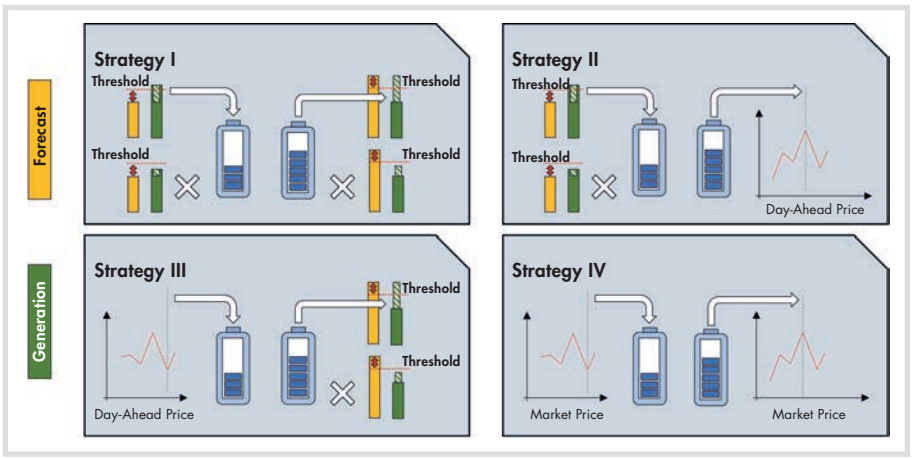


Fig. 1. General principle of the BSS deployment strategies.

rather than balancing energy. The general approach is to use the BSS at the electricity market to store wind generation at times of low prices to be discharged at times of higher prices. The deployment of the BSS considers the corresponding forecasts for the wind generation and the corresponding market prices. A first deployment is planned for the day ahead market, the remaining capacity and power are later deployed for a use at the intraday market. Regardless of the market the BSS is used at, the price difference between the times of charging and discharging must be greater than the transformation losses. The created simulation model is used to optimise the behaviour of the BSS at the different markets as well as the distribution of the BSS capacity and power at the day-ahead and intraday market. To increase the profitability even further, any free capacity of the BSS can be used to compensate positive balancing energy to be sold at the day ahead market.

Comparison of marketing strategies

The analysation of the direct marketing strategies shows, that direct marketing at the day-ahead and intraday-market yields better results than selling only at the day-ahead market. Compensating the deviations of the forecasts at the intra-day markets results in additional costs, but these additional costs are neglected as the costs for balancing energy are greatly reduced (Figure 2). For the day-ahead strategy the forecast errors and thus the cost for balancing energy decrease the income by 28 %. Regardless of the strategy chosen, the results indicate clearly, that the income during the winter months is higher than during the months July to October. The use of the day-ahead and intraday strategy reduces the costs for balancing energy by 88 %. It evens so far that during December and January the balancing energy leads to additional income in case of the day-ahead and intraday strategy. In total, considering the energy generated, the wind power is sold at 28.2 €/MWh for the day-ahead strategy and 31.2 €/MWh (further referred to as wind generation value) for the day-ahead and intraday strategy. In total, the balancing energy costs reduce the value of wind generation by 1.25 €/MWh for direct marketing at the day-ahead and intraday market. This result is comparable with von Roon's work [16], who evaluated the cost effects of balancing energy for wind energy under direct marketing in Germany. According to von Roon the effect of balancing energy through forecast errors reduces the value of wind generation by up to 2 €/MWh and not all forecast errors necessarily result in additional costs. Since the day-ahead and intraday strategy shows more promising results, the remaining analysations are done exclusively this strategy.

Regardless of the marketing strategy chosen, grid parity won't be reached with generation costs for Germany of 53 €/MWh to 96 €/MWh [17]. This would pose a problem if a new wind generator would be marketed right away at the liberalised electricity market only. The generator considered in this research has been running by means of funding for 13 years. Assuming that during those 13 years a reimbursement of the investment costs has happened, the generation costs should only consider the variable costs of the wind generation. They can be assumed with 25 €/MWh to 31 €/MWh [17] making the direct marketing approach economically feasible after funding has expired.

Evaluation of the balancing energy demands

The results of the two marketing strategies call for a deeper analysation of the positive and negative balancing energy. The course of the balancing energy (Figure 3) reveals, that the peaks of the positive balancing energy reach 94 % and the negative balancing energy 84 % of the installed capacity. On a first glance, the course of the balancing energy seems ideal to be compensated by a BSS, as positive and negative balancing energy alternate regularly. However, not all balancing energy results in additional costs by considering the results of the two marketing strategies [18]. Depending on the augury of the balancing energy and the corresponding balancing energy prices either costs or income will. This circumstance on its own would not be a problem if balancing energy prices would be settled in a similar way as market prices. This is not the case, as balancing energy prices are not available at the time of balancing energy occurrence, they are calculated in a first clearing a month after delivery and finales after a second clearing 15 months later [8].

The analysation of total and average costs and income clustered by augury and magnitude of balancing energy (Figure 4), shows clearly, that negative balancing energy almost always results in costs, while this is not the case for positive balancing energy. Especially positive balancing energies with a low magnitude generates more income than costs. Even though the aver-

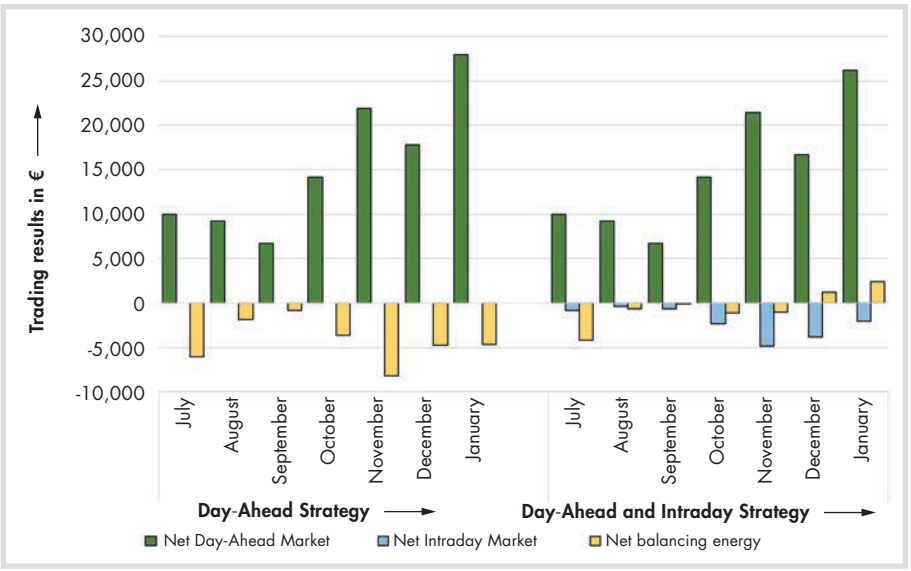


Fig. 2. Monthly trading results for the different marketing strategies.

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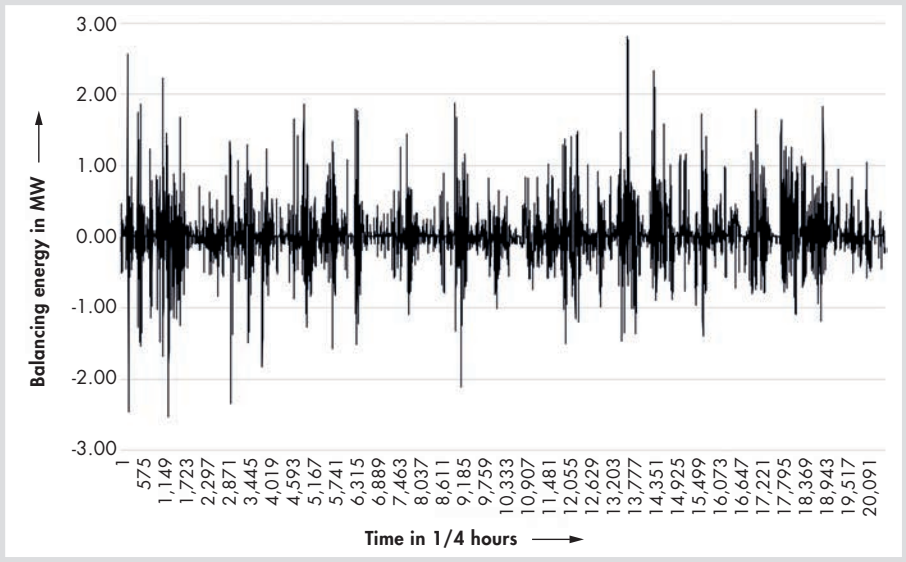


Fig. 3. Course of balancing energy for a 3 MW wind turbine from July 2016 to January 2017.

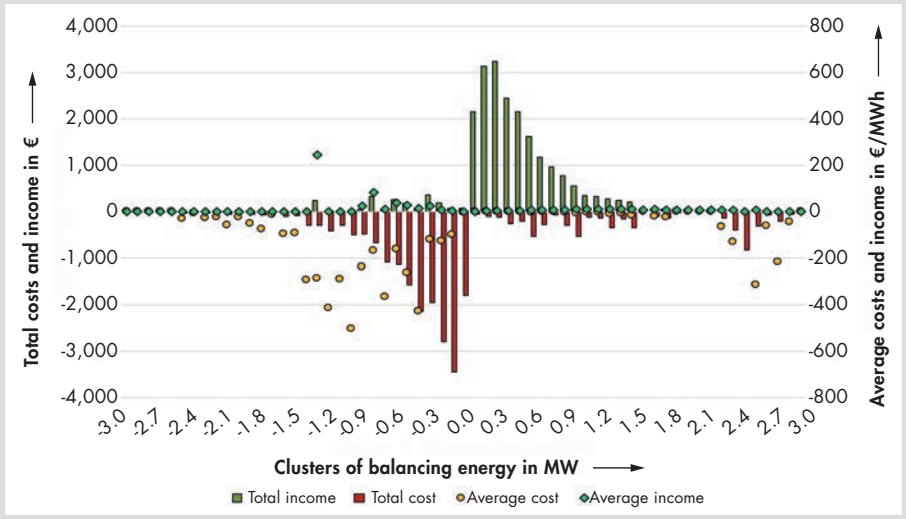


Fig. 4. Results of balancing energy analysation.

age income of positive balancing energy is rather low, compensating would reduce the profitability of wind energy marketing and should thus be prevented. Negative balancing energy on the other hand can be compensated regardless of the magnitude, as with exception of one cluster, negative balancing energy results in additional costs. These results correlate well with the findings of von Roon [16] for Germany. While this statement is generally true for the used data pool, it must be considered that there is only a limited amount of data available. To draw a resilient general conclusion, more data is required.

Evaluation of the economic effects of the deployment of different BSS

The use of the BSS will increase the average price of wind energy beyond the current value of 31.2 €/MWh. The question at hand is, whether the increase will be enough to ensure an amortisation of BSS. The resulting values of wind generation differ greatly depending on the chosen strategy (Figure 5). The results indicate very clearly, that the highest additional value for the wind generation can be generated by using Strategy IV for the deployment of the BSS. The results suggest, that the price difference on the considered markets is sufficient to lead to a regular use of the BSS. The advantage of using Strategy IV gets more significant the higher the capacity of the BSS gets. This effect is a result of the limited amount of balancing energy occurrences at disposal. Of the strategies focussing solely on the compensation of balancing energy, Strategy II reaches the most promising results, as the energy stored in the BSS would normally generate costs and is sold for the best price at the day-ahead market. This is the shortcoming of Strategy III, where the energy used to compensate negative balancing energy needs to be bought at the day-ahead market, even if the chosen price is low. The results for Strategy I to Strategy III do not clearly indicate whether the capacity or the installed power of the BSS are the limiting factor for a further increase in wind generation value, which is not the case in Strategy IV. The results clearly show, that an increase in capacity has a by far larger effect on the value of the wind generation than the installed power of the BSS.

The downside of the BSS usage gets visible when the amortisation durations are considered. None of the strategies on its own will lead to satisfying results, as the additional income from using the BSS is too low to reimburse the high investment costs. The best results are reached while using Strategy IV for the BSS, with either a capacity of 1.35 MWh or a capacity of 2.7 MWh, both with an installed power of 1 MW. Interestingly enough it seems, that for these two capacities, the power is irrelevant in perspective of amortisation duration. In both cases amortisation durations of approximately 81 years can be reached, which are by far too high to represent a sensible investment. Even though, the other strategies do not reach profitable results either, in each case the 1 MW, 1.35 MWh BSS reaches the best results.

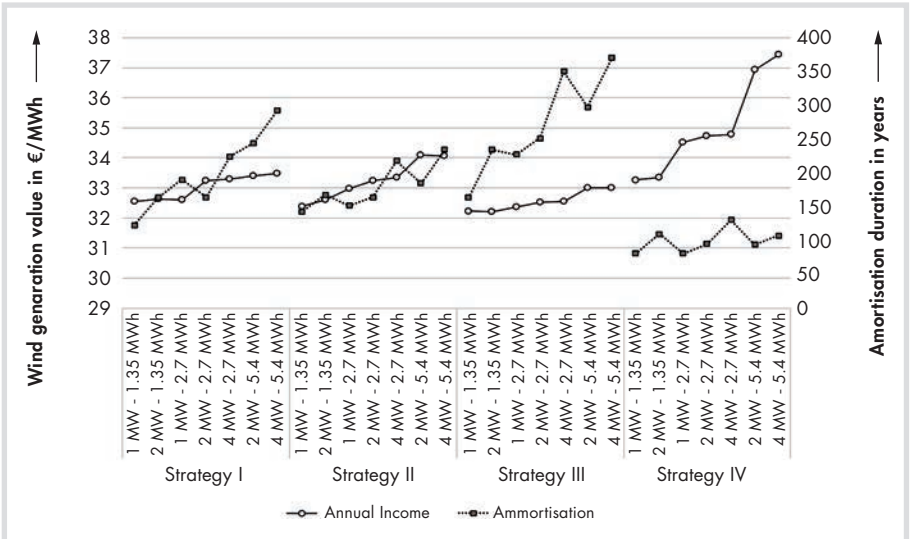


Fig. 5. Wind generation value and amortisation duration for different BSS types and deployment strategies.

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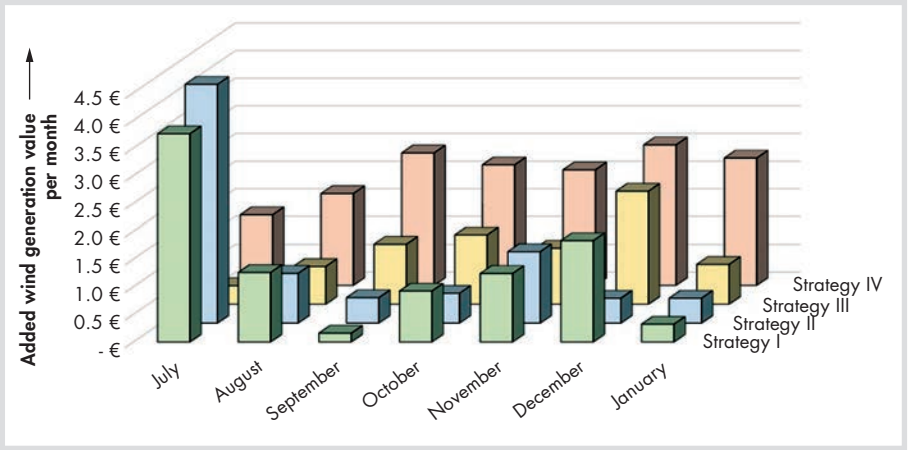


Fig. 6. Added wind generation value per month for the different BSS deployment strategies.

The total value of wind generation after deployment of a BSS needs to be broken down further. The results from the different months in the data pool show great variations for the monthly increase in wind generation value (Figure 6). For a better overview, only the results for the 1 MW, 1.35 MW BSS are shown, but the general conclusion is the same for other BSS parameters.

The strategies focusing on compensating positive balancing energy (Strategy I and II) show comparable results, with an average increase of 1.4 €/MWh for Strategy I and 1.2 €/MWh for Strategy II. In both cases the value increases for July are well above the average with 3.8 €/MWh for Strategy I and 4.3 €/MWh for Strategy II. This suggests that high costs in positive balancing energy occur in that month. For the remaining months, the monthly value increase doesn't reach that high values. For Strategy III (average increase 1.0 €/MWh) the highest monthly value increase results in December (2.0 €/MWh), a result that also translates to Strategy I, but not to Strategy II. This suggests that in December the costs for balancing energy mostly results from negative balancing energy as only the strategies focussing on compensating this energy yield good results. For Strategy IV from September onwards similar monthly value increases can be observed, showing little variations. Only in July and August the monthly value increases fall below the average value increase of 2.1 €/MWh.

These results suggest, that the storage strategy could be swapped between the different months, leading to a better profitability. Generally, Strategy IV is to be preferred over the other strategies, with exception to July, where Strategy II is to be preferred. Given the circumstances that these results are representative for each year of operation and a year would only consist of the months represented in the data pool, changing the BSS deployment strategy to Strategy II in July and Strategy IV for the remaining months would result in an average value increase of 2.5 €/MWh, an increase of 21 %. Under these circumstances the amortisation duration would be reduced by 16 % to 68 years. While this amortisation duration still is longer than the expected life time of a BSS, it shows, that the choice of the BSS deployment strategy needs to be optimised, not only the deployment itself.

While the combination of BSS and wind generation my not seem economically feasible at this point, future developments and the possibility of funding need to be considered. Battery prices have been dropping drastically the last years [19], this development is expected to continue further [20]. Additionally, energy prices are expected to increase, as is the spread between off-peak and peak prices [21] at the electricity market, making Strategy IV more profitable.

Conclusion

Selling wind power at the liberalised electricity market leads to challenges arising from the volatility and uncertainty of wind generation. Forecasts generally do a good job when it comes to predicting the actual generation, but still prediction errors happen, leading to deviations and finally resulting in balancing energy. Trading the wind energy at the day-ahead market only leaves, due to the time window of market interaction, a lot of room for forecast changes and resulting in large deviations between traded energy and actual generation. As a result, costs for balancing energy are high. By adjusting the traded amounts of energy at the intraday market to better fit the available forecasts, balancing energy costs can be reduced. As a result, additional costs at the intraday market can occur. In total marketing wind generation at the day-ahead and intraday market (wind generation value of 31.2 €/MWh) is more profitable than marketing just at the day-ahead market (wind generation value of 28.2 €/MWh). The cost reductions in balancing energy exceed the additional costs at the intraday market.

Comparing these values with the generation costs of 53 €/MWh to 96 €/MWh [17] shows that grid parity is not yet reached, which is why funding is still required. After funding has expired for a wind turbine und under the assumption that investment costs have been reimbursed, the wind generation value can be compared to the variable costs. With 25 €/MWh to 31 €/MWh [17] these are below the values for a direct marketing at the day-ahead and intraday market, making the direct marketing approach economically feasible once funding has expired.

The introduction of a BSS leads to a further increase of the wind generation value, ranging from 32.2 €/MWh to 37.5 €/MWh depending on the BSS parameters and the chosen deployment strategy. Regardless of these two aspects the additional income generated by the BSS is not sufficient to ensure amortisation, with amortisation durations ranging from 81 years to 370 years, with Strategy IV yielding the best results. A BSS with an installed power of 1 MW and an installed capacity of 1.35 MWh resulted in the highest values for each deployment strategy. In this matter, the results of this paper reflect the results of previous research, where the approach to use storage systems to enhance the profitability of wind generation shows no economic feasibility.

An analysation of the average monthly value increase for this BSS results in values ranging from 0.3 €/MWh to 4.3 €/MWh depending on the month and deployment strategy. The strategies focussing on the compensation of balancing energy show inferior results, with the sole compensation of negative balancing energy (Strategy III) having the worst results. Regardless of the BSS strategy chosen, the wind generation value increases differ greatly from month to month. Swapping strategies between the different months looks promising, as the average value increase can be ramped up to 2.4 €/MWh. With this optimisation of deployment strategy each month the amortisation time can be brought down to 68 years, which is still too high to render the BSS profitable.

It needs to be considered, that the results generated in this research have a limited data base. For more resilient results, especially when it comes to the conclusion about the added value for each month, more data needs to be considered. It is therefore recommended to apply the models and calculations in due time, when data on the wind generation and forecasts for a longer period of time are available.

The research has shown that, given the considered data, the inclusion of a BSS is not economically feasible at this point. But the rapid development of battery prices and the development of future market prices at the energy only market need to be considered. Battery prices are expected to go down further [20], while market prices

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and more importantly the price spread is expected to go up [21]. It is therefore recommended to keep re-evaluating the profitability of storage systems and keep developing new deployment cases and strategies. Additionally, the possibility of getting the investment funded by national or international funding agencies needs to be considered to gather first experience with the actual real-life deployment of a BSS. Therefore, a follow up project to the research project Windvermarktung is planned, with the goal to implement and test a BSS in combination with wind generation.

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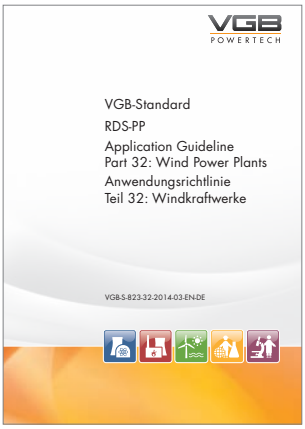
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Ausgabe/Edition 2014 – VGB-S-823-32-2014-03-EN-DE
DIN A4, 314 Seiten, Preis (Grundwerk): VGB-Mitglieder* 280,– €, Nichtmitglieder 375,– € + Versandkosten und MwSt.
DIN A4, 314 pages, price (Basis edition): VGB members* € 280.–, Non members € 375.– + shipping, handling and VAT

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