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Energy storage facilities are changing the energy system and already within a year they can become fully profitable in Poland

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Abstract

The article presents the current situation in the global energy storage market and the prospects for the development of this sector. It also presents a way to integrate large energy storage in the Polish energy system (required necessary IT systems). Finally, an analysis of the profitability of the operation of the storage facility in the current market situation is made.

Keywords: energy storage facilities, IT systems, Polish energy system, energy market, economic simulation of the storage facility

Introduction

While in Poland we are discussing and planning the transition and the move away from coal (and more broadly from fossil fuels), California is rapidly realizing this and wants to achieve a 90% reduction in CO2 by 2035. With about 50% zero-carbon energy today (30% RES, 10% hydro, 10% nuclear, etc.) - California faces a natural next challenge of how to build a completely zero-carbon system [1], but without nuclear power (development is not anticipated). The idea is an unprecedented development of solar power (large installations) combined with the development of energy storage (battery storage). 100% zero-carbon is to be achieved in 2045 using expansion of installed capacity from 35 GW today to about 73 GW in 2030 and up to about 180 GW in 2045. - mainly by increasing the capacity of large PV and storage facilities. These are to play a key role in the new energy system - California is the world leader in their use. While in 2019 the capacity of (battery) storage facilities was 250 MW, more than 5,000 MW are now in operation and is expected to reach almost 20,000 MW in a short while (2030), with a target of 52,000 MW (2045). California is not concerned about the much-discussed problems of rare earth elements availability, the price of storage, or hypothetical fire hazards. Already today, tracking daily power changes in the California system shows exactly similar patterns to those of homes (located in southern climate areas) equipped with PW and storage -

daily generation is slowly dominated by solar PV (maximum during the day), which additionally recharge storage coming into service during the afternoon peak as the intensity of the sun decreases and then taking over much of the generation (usually during the 4-hour discharge period). What is impressive is not only the fact that the storage is already operating as a source of power generation, but especially how quickly they have entered the system (4 years of installation of about 5 GW) and future expansion plans. If the concept succeeds - California will be the first "new" energy system in which battery storage facilities take over as the primary source of supply security in the absence of RES generation (in this case, overnight). Of course, weaknesses can be found right away - the California experience cannot be easily transferred to other areas (e.g., Poland) due to weather conditions - there the sun allows uninterrupted generation practically during the whole year) and in a lesser way must secure heating needs. Nevertheless - the RES plus storage model is becoming an attractive concept for an alternative and future-oriented energy system, which can be very competitive with the introduction of nuclear power, which is also being pushed in Poland. The development of battery energy storage is certainly a foregone conclusion. Currently, the largest storage facilities [2] (just in California) reach 400MW/1600MWh (Vistra Energy Corporation), in Florida Manatee Energy Storage Center Project (409MW/900MWh) or 300MW/450MWh Victorian Big Battery (Australia). The capacities are thus comparable to medium-sized power units, of course, the mode of operation itself is different - discharge cycles are usually about 4 hours - given which the largest available capacities (as of today) are just 1600 MWh. However, changes are proceeding exponentially - one can expect a doubling of available capacity (and capacity) in the next 5 years. Global capacity planned in the systems of many countries is growing rapidly - although Europe seems today to be somewhat behind the impressive plans of California (as well as some Asian countries) and so Germany will have about 35 GW in 2037, UK 20 GW by 2030. It's worth remembering that Poland has already issued ca. 7 GW of connection conditions for storage facilities. European storage is also somewhat smaller in constructed capacities (the largest a few tens of MW) yet it is in Poland that the largest European storage facility is currently planned (205MW/820MWh). The final profitability of the construction and operation of storage is widely debated. They usually try to combine different revenue models - participation in the power market (here it is worth noting the large share of storage in the Polish market), direct operation using the daily price spread (and co-daily discharge cycles), and also assistance in direct frequency regulation for distribution systems (here battery storages with a response time of about 0.02 seconds are unrivaled). Pricing data at present is very divergent, but it can be expected that in the near term the cost analogous to LCOE will be (optimistically) at the level of $100/MWh (although some reports today show a figure twice as high [3]) or even further a strong drop by 2035 (which shows on what spreads storage can operate), and available reports from California already show cost-effective operation at $70-100 per year per kW of installed capacity [4]. The technology is neither niche, nor on heavily subsidized terms, but realistically entering the stage of commercial development - there is a rapid increase in available capacity, the capacity of storage factories is growing tremendously, the price is falling, and the construction and installation itself is already a standard process with an extremely short (for an energy system) time. The storage business is also correlated with electromobility (analogous battery production technologies) which will have a strong impact on cost reduction it is already a foregone conclusion that this will be one of the growing markets - this can be seen in the chart below given after [5] - the development of the storage market worldwide (annual investment in storage capacity).

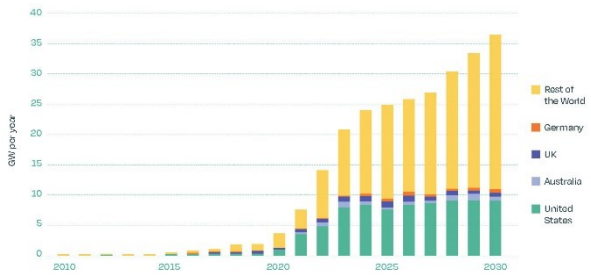

Figure 1: Up-to-date and future forecast investment in energy storage systems [5]

In Poland, regardless of planning and subsequent versions of the energy transition - the technology that will develop the fastest and cheapest will simply win. Storage facilities can be a quick alternative to change and will naturally be built under today's power market contracts. If we build at least half of the planned (7 GW) by 2030 (and it's not impossible), the work of the storage may already be noticed in the system. It will slowly begin to "push" other generation units (coal) out of the market. They may become a threat to the next gas projects (already under pressure from the next iterations of the European climate policy and ambitious reduction targets), but also above all to the very distant (in construction time) nuclear power plants. It should be remembered, however, that unlike in California, in Poland battery energy storage is not a remedy for everything. Our domestic weather conditions cause difficulties in winter months (although of course, more wind farms and especially offshore projects are an idea), but longer periods of system operation without RES generation (a week or two, without wind and sun) are still a threat, and even more so if there are low outside temperatures. Naturally, the Polish power system must have larger amounts of long-term storage (and these are not well developed commercially) or backup units - and here I think the role of gas will remain out of competition. The need to supply system heat (as well as for industrial processes) may provide opportunities for a broader use of gas (steam-gas) systems than it is currently planned, and in a sense for a return to the concept of coal-gas transformation, which in the new Polish conditions could look like RES-storage-gas (in the long-term perspective of 2050, gas could further transform towards a hydrogen economy, which is certainly already behind schedule on its projected development path). The current price trend is favorable - calmness in the gas market, declining prices, surplus of raw material on the market in the face of the standard problems of coal mines. And above all - the market and global processes rather than local plans and strategies will win out. And here are the storage facilities - they are certainly currently winning and the last word in this area has not been said. The only issue of concern is California itself - this is the state that has always invested and changed first - and so was the front-runner for changes in the energy market which resulted in... the great crisis of 2000. Whether this will also happen with storage (a potential crisis) is unknown, but the final victory is certain.

Optimizing methods of utilizing energy storage

The critical element is to correctly identify the suitable business model for energy storage operations. It is highly dependent on national regulations. There are several opportunities, such as the capacity market, the market for flexibility services, the market for system services to the TSO, and price arbitrage. Due to the dynamics of energy storage operation, it is impossible to control the storage using only the operator effectively, and in some cases, such as frequency control services, it is even impossible [6]. As with conventional power units, energy storage requires multiple information systems, each with their own role.

The first system located directly at the energy storage is the BMS (battery management system), responsible for monitoring and diagnosing the battery. This system consists of two main components: CMU (cell monitoring unit) and BMU (battery management unit). The CMU system reads basic parameters such as voltage, current, or temperature, while the BMU is responsible for more complex calculations and diagnostics [7]. Another system is the EMS (energy management system). Its tasks are the

broadest, and its definition is quite flexible. The EMS is responsible for acquiring data from the energy storage through a direct connection to the BMS, and it also enables control of the energy storage, whether through an application interface or integration with external systems. The EMS also allows the integration of multiple sources located in energy storage, such as photovoltaic installation.

For further analysis, two options will be used:

1) The storage facility participates in price arbitrage
2) The energy storage facility provides balancing services to the Transmission System Operator

In the case of the first variant (Figure 2), in addition to the basic systems to be used, there is an optimizer that, based on market data and data on the current generation of RES sources, plans the operation of the storage facility to maximize profit, i.e., stores energy when the market price is too low and sells when the price is high. For such optimization, a series of data is used, such as the price forecast, the generation forecast if the storage cooperates with the RES installation, and the actual market prices. The plan prepared by the optimizer is then sent to the EMS system and, in turn, to the energy storage facility. The storage facility's plan data is also the basis for preparing corresponding orders on the exchange using trading systems.

Figure 2: IT Systems – price arbitrage

In Option 2, 3 additional IT systems should be added to the existing system (Figure 3), which are necessary for proper operation in the balancing market in Poland. The first is the WIRE (Energy Market Information Exchange) system, through which documents such as work programs, portfolios, or bids for energy and balancing power are sent to the TSO. This system communicates with trading systems from the user and operator systems. The second system is SOWE (System for Operational Cooperation with Power Plants), which is used to negotiate planned states of scheduled units and obtain load plans for individual units. From the point of view of frequency services such as FCR or FRR, the critical system is LFC (load and frequency control). This system allows TSOs to remotely control units to balance and maintain frequencies on the grid.

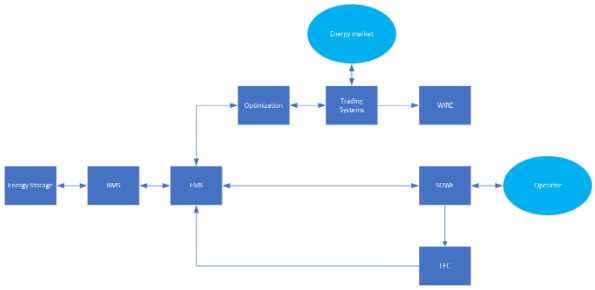

Figure 3: IT Systems – price arbitrage and balancing services

The optimizer could play an additional role in planning participation in specific markets. Such a system would make decisions based on the availability of energy storage and the current market situation, creating a plan for the storage operation for the coming day and considering the provision of various services

Simulation of cost-effectiveness of operation of an energy storage facility in current Polish conditions

A simulation of the profitability of the operation of a storage facility hypothetically operating in the Polish market has been carried out. The operation of the warehouse assumes the use of daily price spread and energy price data - based on TGE fixing February 2024

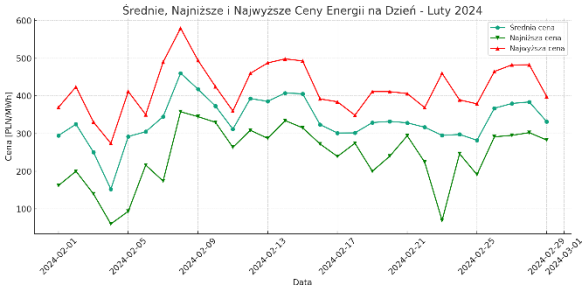

Figure 4: *Price distribution of the Polish Energy Pool February 2024 Daily average prices and maximum and minimum prices.*

The daily average hourly price corresponds to the demand profile and is as follows:

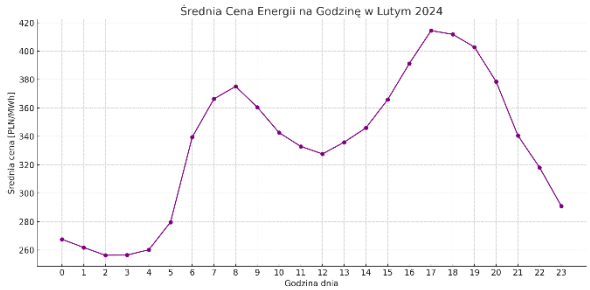

Figure 5: Daily price spread (hourly averages) – Polish Energy Pool February 2024.

Simulation of revenue from storage operation assuming the use of daily price spread is as follows. It is assumed to charge at the lowest daily price (within 1 hour) and discharge within 4 hours at the highest daily prices. Results are presented for 1 MW of storage capacity.

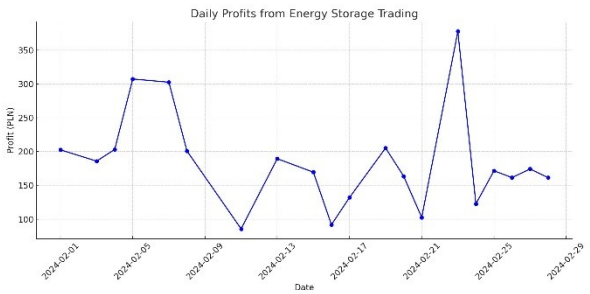

Figure 6: Daily revenue from the operation of a 1 MW storage facility – Polish Energy Pool February 2024.

To sum up - the average possible profit of the operation of buying and selling energy by a 1 MW storage facility, which buys energy in the cheapest hour and sells in the four best hours of the same day, is currently (simulation February 2024) about 185,56 PLN per day. The day with the highest revenue is February 23, 2024, with a result of 377.63 PLN. The day with the lowest revenue is February 11, 2024, with a result of PLN 85.73

Conclusions

It should be remembered, however, that wholesale energy prices in the first quarter of 2024 were at a relatively low level due to relatively warm weather, low consumer demand, and high RES generation. This shows a rally of sorts - the most conservative simulation of revenue from storage operations. Already, average wholesale prices are about 25% higher and the daily spread itself varies widely. Nevertheless, the potential achievable revenues are certainly significantly lower than those presented, among others, in [4], and in Polish conditions warehouses operating only on the daily wholesale price spread do not even reach the profitability threshold. However, it can be assumed that the return on warehouse investments will soon be reached (maybe even by the end of 2024). This is facilitated by the decline in investment prices of storage facilities, as well as the progressive problems of excess RES generation in Polish conditions. Already in March 2024, there are periods with excess RES generation and forced reduction of RES energy offtake by the Transmission System Operator, which allows the building of business models of RES investments integrated with energy storage. The amendment to the Balancing Market rules, which comes into effect in June 2024, may also allow for more revenue if the storage also worked on the RB. Of course, additional subsidies for storage owners are possible in the next phases of the energy transition, but it seems that the energy storage market in Poland may reach equilibrium (cost-effectiveness) already at the turn of 2024/2025, which allows looking favorably on this type of investment.

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