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Energy Storage Integration in European Markets

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Abstract

Purpose of Review Energy storage systems are becoming important agents in electricity markets. They are deployed to support further integration of renewable energy sources and can offer various services to the network operators.

Recent Findings As the European electricity network operation moves toward market-based decision-making, it is necessary to ensure a fair playground for all participants. This implies adaptation of regulatory framework and market rules to allow unobstructed participation of energy storage in markets at all levels.

Summary This paper aims at providing a brief overview of the status of energy storage in European market framework, identifying the obstacles and proposing actions to overcome them.

Keywords Energy storage · European market design · Policy

Introduction

Traditionally operated in centralised way and planned robustly, today's power systems are going through a paradigm shift caused by high penetration of renewable energy sources (RES). Large quantities of RES installed in both the transmission and distribution networks induced changes in ways the two systems are run and planned. To ensure stable grid operation, more and more flexibility sources are necessary, which brought energy storage into the equation as one of the environmentally acceptable options. However, it must be noted that the emission-reducing property of energy storage unfolds at high penetration of RES, while at the lower penetration levels, it can even have the opposite effect. Energy storage is not only now being installed at the transmission and distribution grid levels but also at the end user level to ensure high utilisation of the energy produced by RES. Energy storage is considered for other purposes besides RES integration, such as an alternative to network investments, and as a congestion management tool, changing the traditional approach to network planning.

Energy storage is not a new technology. Pumped hydropower plants have been an important part of the modern power systems since almost their beginning. In the past, they were usually used for energy arbitrage—charging when consumption is low and discharging when it is high. Restructuring of the European power system, which begun in the 1990s and continues today, made way for independent investors instead of the traditional regulated utilities. The independent investors are concerned with ensuring the return on their investments by making profit in the markets. Furthermore, the latest Electricity Directive (EU) 2019/944 [1] prohibits the system operator's ownership over energy storage, requiring that a fully competitive market entity owns and operates storage. It was proven in simulation as well as in practice that investments in energy storage cannot be justified by arbitrage only [2]. Therefore, in order to stimulate investments in energy storage, it is necessary to open multiple markets to energy storage participation.

Drivers and Obstacles

In the document "A Clean Planet for all" [3], European Commission presented a long-term strategy to direct EU toward a competitive and climate-neutral economy. According to this document, energy storage will have an important role in reaching CO_2 neutrality by 2050. The issue of competing technologies, such as demand side management, is presented

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in the said document as well. However, the conclusion is drawn that, in order to reach the EU-level goal of total carbon neutrality by 2050, all the technologies will need to be employed together.

Although it was shown that increasing the usage of RES in combination with batteries decreases negative impacts on the environment, it can also cause increase in fresh water contamination and depletion of mineral sources [4]. Negative implications of battery storage are considered by the European Commission's European Battery Alliance. The main goal of this incentive is to stimulate research and investments related to sustainable battery technologies, accounting for environmental impacts of their production, utilisation, and disposal [5].

Long-term energy storage is a standing issue in power systems today [6]. The long-term energy storage services were traditionally provided by hydropower plants [2]. Their main downside is the scalability issue—it is infeasible to build small-scale pumped-hydro facilities. This is one of the reasons why so much effort is placed in investigating power-to-gas (P2G or P2X) technology, e.g. hydrogen storage [3, 7].

Many European countries with weaker interconnection capacities and internal grids vulnerable to congestion are turning to energy storage [8]. In this context, using energy storage for ensuring the N-1 criterion was investigated [9]. Moreover, many countries with autonomous islands are replacing diesel generators on these islands with hybrid RES storage facilities to avoid high costs of fuel imports and reduce contamination in the islands [10, 11].

Legal and Regulatory Framework

Energy storage was considered in many studies a support for photovoltaic systems and various other applications in the distribution grids. It was shown in [12] that there is a large potential for distributed battery storage systems, with conclusion that grid planners and policymakers should start considering them a system asset. However, Electricity Directive [1] from "Clean energy for all Europeans" legislative package defines only special circumstances under which the transmission and distribution system operators are allowed the ownership of energy storage. These circumstances include scenarios in which it can be proven that the system operator is the only agent ready to invest in energy storage within a specified time frame and that the storage system is indispensable for stable operation of the grid. As the directives are legal documents that require implementation into the member states' national laws, the consequences of this provision remain to be seen.

A recent report published by the Agency for Cooperation of Energy Regulators (ACER) [13] provides an overview of network tariffs charged to the generators, consumers, and energy storage. The report differentiates pumped-hydro and other storage facilities, but for the sake of brevity, we take them as one. About half of the countries represented in the report do not charge generators for injection charges, and therefore, the energy storage is not charged either. However, 13 countries (Austria, Belgium, Denmark, Finland, France, Ireland, Norway, Portugal, Romania, Slovak Republic, Spain, Sweden, and the UK) apply injection charges to the generators. Out of these countries, the same charges apply to the storage as well, except for Slovak Republic and Belgium, as well as France and the UK in some cases. Withdrawal charges are applicable to the consumers in all the represented countries, but there are some that explicitly exclude storage facilities from these charges (Italy, Latvia, Lithuania, Poland, Portugal, Slovak Republic, and Slovenia). Therefore, with some exceptions, in the countries that have some kind of injection network charge setup, energy storage is charged both when withdrawing and injecting power into the grid (Fig. 1). The fact that it happens in many European countries is a result of energy storage being seen not only as a stand-alone entity but also as a hybrid between a load and a generator. This is problematic because it makes energy storage less competitive to generating units and consumers, who pay the network charges only once.

Similarly, distribution grid-connected energy storage is often considered a combination of a consumer and a producer. For example, the Croatian Distribution grid code does not include energy storage as a separate entity, but defines it as a

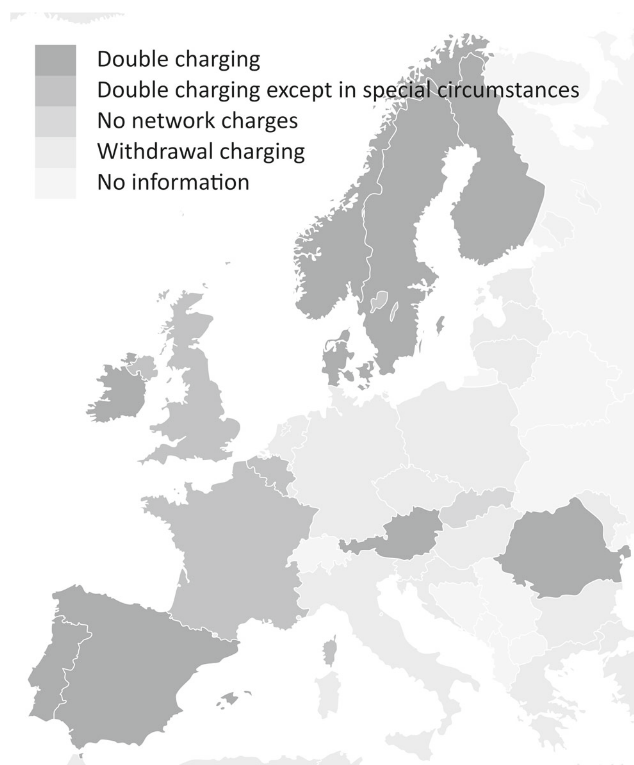

Fig. 1 Network charges for energy storage in selected European countries

subset of prosumers [14]. This categorisation implies that energy storage connected to the distribution grid can only trade electricity with its supplier in the retail market and cannot gain access to the wholesale market on its own nor through an aggregator. A contract with a supplier entails not only energy costs but also VAT, renewable energy support charges, and other socialised charges that consumers pay, but not the generators. Consequently, energy storage connected to the distribution grid has even more limited profit opportunities in comparison with the ones connected to the transmission grid. There are, however, countries such as Italy where distribution grid-connected energy storage systems are regulated fairly as stand-alone entities. Potential for using energy storage for active and reactive power regulation in Italian low-voltage grids is explored in [15].

Techno-Economic Properties

While pumped-hydro storage is a mature technology without forecasted cost reductions until 2030, the remaining energy storage technologies have a potential for installation cost reductions, ranging from 20% for compressed air storage to between 54 and 61% for lithium-ion battery technologies [16]. Such large cost reduction potential for electrochemical storage technologies is owed to their low maturity level. Similarly to cost reductions, improvement in technical parameters for all storage technologies is expected in the coming years. Because of their maturity, large changes in technical parameters such as energy efficiency, energy density, and cycle life are not anticipated for the pumped-hydro and compressed air units. On the other hand, new materials and inventions are deemed to increase these properties for all other storage technologies, especially electrochemical. For example, cycle life is expected to double for selected lithium-ion as well as lead-acid technologies and to increase by 50% for sodium-based batteries [16]. A reader interested in a thorough overview of the state of the art in energy storage technologies and recommendations for future research directions should refer to [6].

Energy storage technologies' costs and benefits were investigated by many researchers, e.g. [17–19]. The general conclusion is that the costs are currently too high to justify the investments in energy storage for most applications. However, various factors can influence their profitability, e.g. political decisions or incentive schemes for other technologies [8]. Prices of batteries are mostly driven down by the growth of electric vehicle and consumer electronics industry. Programmes such as the World Bank's incentive for investments in energy storage in less-developed countries [20] are certain to push the prices even lower. By directing the research activities and promoting recycling and reuse of old batteries, incentives like European Battery Alliance will influence future price trends at the EU and global level as well.

Market Participation

The "Clean energy for all Europeans" package aims through the electricity regulation [21] at unifying the wholesale markets throughout Europe. Although organisational differences between various day-ahead markets do exist, the issue of unified day-ahead electricity market for the entire Europe was successfully tackled by introducing the Euphemia algorithm [22, 23]. Nonetheless, market rules are specific to each country so the integration of energy storage remains an issue in most of Europe. Article 8 of Regulation (EU) 2019/243 [21] sets a rule for minimum bid size of 500 kW or less in all day-ahead and intraday markets, which will make the market participation a more attainable goal for many smaller system assets. The same article sets the imbalance settlement period at 15 min, unless regulatory authorities allow an exception. This will be beneficial for the energy storage systems' participation in balancing markets.

As a market participant, energy storage is surrounded by controversies caused by its dual nature. It was shown in [24] that, opposite to the economic theory's idea of imperfect market competition, adding storage to markets in some circumstances actually decreases social welfare. While most researchers have considered only one strategic energy storage system and shown that it can benefit from strategic price-setting or capacity withholding, the authors in [25] have shown that increasing the number of energy storage systems that behave strategically limits their respective profits, which is in line with the economic theory. Decision-makers have tried in various ways to overcome obstacles for competitive energy storage, from EU's ban on regulated entity-owned storage systems, to the US regulators' attempts to increase competition in markets [26].

Rules for pre-qualification process for frequency reserve market participation in Germany contain a specific section dedicated to only energy storage. Specific tests are devised for energy storage to prove the ability to perform frequency regulation. The storage unit is tested in alternating 15-min cycles of regulation provision and idle mode, repeating until the storage capacity is depleted. If the entire control reserve is called, the storage must be activated within 30 s for frequency control reserve (FCR), 5 min for automatic frequency restoration reserve (aFRR), and 15 min for manual frequency restoration reserve (mFRR) [27]. The positive example of German frequency reserve market stands out as the rest of the European countries struggle to keep up with the new developments in the EU's electricity sector.

In European Resource Adequacy Assessment Methodology Proposal by the ENTSOe [28], energy storage is given a separate role from the generators and consumers. However, capacity market rules in most European countries place the minimum capacity offers at 2 GW, making it impossible for the smaller assets to participate. Capacity mechanisms employed in European countries are strategic reserve, demand response schemes, and market-based mechanisms. Market-based capacity mechanisms exist in Italy and Poland [29]. Capacity mechanisms that allow energy storage participation are still a rarity because of the storage's specific properties and currently only the UK capacity market admits storage facilities. In order to ensure that various technologies can provide the capacity they offer in capacity markets, UK's network operator attributes to all of them the de-rating factors. For energy storage, these factors depend on their discharge duration. For example, the current T-3 auction energy storage with 30-min duration has a de-rating factor of 10.59%, while the storage with longest duration (over 5.5 h) has 95.08% [30].

Conclusion

Conclusions drawn based on the information presented in the paper are listed below.

1. It is time to introduce incentives for the storage technologies alone or in combination with RES.

Incentives did miracles for RES integration in almost all European countries, and energy storage was for a long time piggybacking on the RES hype. Although enabling RES integration remains the most prominent use case for energy storage, without incentives designed specifically for energy storage, we cannot expect to see the rise of energy storage installations, regardless of the end use. As there is a potential for incentivising energy storage utilisation by carefully designing retail electricity market tariffs, the incentives need not be aimed at investment cost reductions only.

2. Legal framework must be adapted to enable market participation of energy storage.

Legal framework at the EU level sets firm guidelines for energy storage integration. However, many countries adapt the European Commission's regulations into their national laws by translation, only to satisfy the form. Energy storage potential varies from country to country so the national laws should also be specific to each country, reflecting the said potential. The latest regulations place prohibitions on system operator-owned energy storage, limiting the potential of using it as a system asset.

3. Regulatory framework must include energy storage as a stand-alone agent.

Grid codes in many European countries consider energy storage as consumers while charging and generators when discharging, which makes them compliant to various regulations pertaining to both market participants. These regulations tend to reduce the energy storage's potential for profit, making them less attractive to investors. The authors of this paper advocate the standpoint that energy storage is not an end user of electricity and should not be charged: (i) the retail price, but the whole sale price instead; (ii) renewable support fees; (iii) network fees; (iv) peak power payments.

4. Market rules need to be relaxed and trading times shortened to enable market participation of energy storage.

This is true for energy, capacity, and reserve markets in many European countries. There are rules in existence that limit the minimum size of market participants, as well as the rules that set requirements on the duration of the service provided by an agent. Those rules prevent many energy storage systems from market participation and should be relaxed to increase market competition.

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Compliance with Ethical Standards

Disclaimer The contents of this document are the sole responsibility of authors and can under no circumstances be regarded as reflecting the position of the European Union.

References

1. Directive (EU) 2019/944 of the European parliament and of the council of 5 June 2019 on common rules for the internal market for electricity and amending directive 2012/27/EU. 2019. URL https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L0944. Legislative Body: EP, CONSIL Library Catalog: EUR-Lex. Accessed 14 Jun 2020.
2. Gaudard L, Madani K. Energy storage race: has the monopoly of pumped-storage in Europe come to an end? Energy Policy. 2019;126:22–9. https://doi.org/10.1016/j.enpol.2018.11.003.
3. A Clean Planet for all. 2018. URL https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773. Accessed 19 Jun 2020.
4. Berrill P, Arvesen A, Scholz Y, Gils HC, Hertwich EG. Environmental impacts of high penetration renewable energy scenarios for Europe. Environ Res Lett. 2016;11(1):014012. https://doi.org/10.1088/1748-9326/11/1/014012.
5. Strategic Action Plan on Batteries (report). 2019. URL https://www.eesc.europa.eu/en/our-work/opinions-information-reports/

opinions/strategic-action-plan-batteries-report. Library Catalog: www.eesc.europa.eu. Accessed 3 Sept 2020.
6. Koohi-Fayegh S, Rosen MA. A review of energy storage types, applications and recent developments. J Energy Storage. 2020;27:101047. https://doi.org/10.1016/j.est.2019.101047 http://www.sciencedirect.com/science/article/pii/S2352152X19306012.
7. Wulf C, LinÃŸen J, Zapp P. Review of power-to-gas projects in Europe. Energy Procedia. 2018;155:367–78. https://doi.org/10.1016/j.egypro.2018.11.041.
8. Potau X, Leistner S, Morrison G. Battery promoting policies in selected member states. 2018. https://ec.europa.eu/energy/sites/ener/files/policy_analysis_-_battery_promoting_policies_in_selected_member_states.pdf. Accessed 3 Sept 2020.
9. Luburić Z, Pandžić H, Plavšić T, Teklić L, Valentić V. Assessment of N-1 criteria using energy storage. In: 2017 IEEE International Conference on Environment and Electrical Engineering and 2017 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I CPS Europe). 2017. pp. 1–6. https://doi.org/10.1109/EEEIC.2017.7977587.
10. How the bridge projects are addressing the battery topic? 2018.
11. Pavić I, Luburić Z, Pandžić H, Capuder T, Andročec I. Defining and evaluating use cases for battery energy storage investments: case study in Croatia. Energies. 2019;12(3):376. https://doi.org/10.3390/en12030376 Number: 3.
12. Müller M, Viernstein L, Truong CN, Eiting A, Hesse HC, Witzmann R, et al. Evaluation of grid-level adaptability for stationary battery energy storage system applications in Europe. J Energy Storage. 2017;9:1–11. https://doi.org/10.1016/j.est.2016.11.005 URL http://www.sciencedirect.com/science/article/pii/S2352152X16302675.
13. Acer practice report on transmission tariff methodologies in Europe. 2019. URL https://www.acer.europa.eu/Official−documents/Acts−of−the−Agency/Publication/ACER%20Practice%20report%20on%20transmission%20tariff%20methodologies%20in%20Europe.pdf. Accessed 4 Jun 2020.
14. Mrežna pravila distribucijskog sustava nn 74/2018. 2018. URL https://narodne-novine.nn.hr/clanci/sluzbeni/2018−08−74−1539.html. Accessed 3 Sept 2020.
15. Bignucolo F, Cerretti A, Coppo M, Savio A, Turri R. Effects of energy storage systems grid code requirements on interface protection performances in low voltage networks. Energies. 2017;10(3):387. https://doi.org/10.3390/en10030387 Number: 3 Publisher: Multidisciplinary Digital Publishing Institute.
16. IRENA. Electricity storage and renewables: costs and markets to 2030. 2017.
17. Lai CS, McCulloch MD. Levelized cost of electricity for solar photovoltaic and electrical energy storage. Appl Energy. 2017;190:191–203. https://doi.org/10.1016/j.apenergy.2016.12.153.
18. Percebois J, Pommeret S. Storage cost induced by a large substitution of nuclear by intermittent renewable energies: the French case. Energy Policy. 2019;135:111067. https://doi.org/10.1016/j.enpol.2019.111067.
19. Varghese S, Sioshansi R. The price is right? How pricing and incentive mechanisms in California incentivize building distributed hybrid solar and energy-storage systems. Energy Policy. 2020;138:111242. https://doi.org/10.1016/j.enpol.2020.111242.
20. World Bank Group Commits $1 Billion for Battery Storage to Ramp Up Renewable Energy Globally. URL https://www.worldbank.org/en/news/press-release/2018/09/26/world-bank-group-commits-1-billion-for-battery-storage-to-ramp-up-renewable-energy-globally. Library Catalog: www.worldbank.org. Accessed 3 Sept 2020.
21. Regulation (EU) 2019/943 of the European parliament and of the council of 5 June 2019 on the internal market for electricity. 2019. URL https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0943. Legislative Body: EP, CONSIL Library Catalog: EUR-Lex. Accessed 18 Jun 2020.
22. Dourbois GA, Biskas PN. European market coupling algorithm incorporating clearing conditions of block and complex orders. In: 2015 IEEE Eindhoven PowerTech. 2015. p. 1–6. https://doi.org/10.1109/PTC.2015.7232562
23. NEMO Committee, Euphemia public description, Single price coupling algorithm. https://www.nordpoolgroup.com/globalassets/download-center/single-day-ahead-coupling/euphemia-public-description.pdf. Accessed 3 Sept 2020.
24. Sioshansi R. When energy storage reduces social welfare. Energy Econ. 2014;41:106–16. https://doi.org/10.1016/j.eneco.2013.09.027.
25. Pandžić K, Pandzic H, Kuzle I. Virtual storage plant offering strategy in the day-ahead electricity market. Int J Electr Power Energy Syst. 2019;104:401–13. https://doi.org/10.1016/j.ijepes.2018.07.006.
26. Tejada-Arango DA, Siddiqui AS, Wogrin S, Centeno E. A review of energy storage system legislation in the US and the European Union. Curr Sustain/Renew Energy Rep. 2019;6(1):22–8. https://doi.org/10.1007/s40518-019-00122-7.
27. Handbuch für die Benutzung der Präqualifikationsplattform ("PQ-Portal") der deutschen Übertragungsnetzbetreiber. 2020. URL https://pq-portal.energy/Portals/1/Handbuch%202020-04-01%20Praqualifikations-Portal%20v3_5.pdf. Accessed 3 Sept 2020.
28. Joyeau A. European resource adequacy assessment-methodology proposal in accordance with Article 23 of the Electricity Regulation of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast). 2019.
29. State aid: Commission approves 6 capacity mechanisms. 2018. URL https://ec.europa.eu/commission/presscorner/detail/en/IP_18_682. Library Catalog: ec.europa.eu. Accessed 18 Jun 2020.
30. nationalgridESO: Capacity market auction guidelines. 2020. URL https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/Auction%20Guidelines%202020_T-1_T-3_T-4.pdf. Accessed 18 Jun 2020.