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ENERGY MARKETS (R SIOSHANSI AND A MOUSAVIAN, SECTION EDITORS)

A Review of Energy Storage System Legislation in the US and the European Union

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Abstract

Purpose of Review This paper focuses on the current possibilities for energy storage systems (ESS) to participate in different power system services. ESS can provide multiple services such as spinning reserve, deferral upgrades, and energy management. However, this versatility of ESS poses a challenge for regulators in designing markets where ESS have prominent roles. We assess recent regulatory proposals in the US and the EU in order to understand their implications for ESS.

Recent Findings These proposals attempt to improve the current rules for efficient ESS deployment. Nevertheless, they have different approaches to the same problem. We discuss these differences in an attempt to shed light on the regulatory debate about ESS ownership and market design.

Summary The successful integration of ESS will depend on proper incentives to provide multiple services without hampering the current market structure. New asset definitions could help to define the roles of ESS as either a generation or a transmission asset.

Keywords Energy storage systems · Regulatory framework · Market design · Variable renewable energy sources · Asset definition

Introduction

Population growth around the world, climate change, and so-called green policies are demanding increasing energy production from variable renewable energy sources (vRES) [1]. Due to government support and market reforms, wind and solar generation has been increasing over the last decade [2]. Nevertheless, integrating these vast quantities of vRES into current electric power systems leads to several technical and economic challenges. For instance, the planning and operation of power systems are more difficult to manage due to the intermittent production of vRES. Furthermore, potential vRES locations are frequently geographically scattered and rarely correlated with demand profiles. These characteristics pose challenges for voltage and frequency regulation specifically and the adequacy of power systems generally [3]. As a consequence, power systems operation and planning should become more flexible and embrace new technologies that could facilitate the integration of vRES [4]. Flexibility in power systems can be attained through many different approaches such as demand-side management, vRES curtailment, intraday markets, integration of different energy sectors (e.g., electricity, transport, heat), reinforcement of the transmission infrastructure, addition of flexible generation technologies (e.g., open cycle gas turbines), and energy storage systems (ESS) [5, 6]. In this review, we focus on ESS without distinguishing by technology type (i.e., mechanical, chemical, electrochemical, thermal, and electrical), since the current regulation is neutral from a technological point of view for ESS.

ESS are often touted as potential solutions for vRES integration [7, 8]. For instance, the Hornsdale Power Reserve Battery Energy Storage System in Jamestown, Australia, is a recent prominent case because it helped to integrate wind farms in its region [9]. This case has shown that ESS can provide multiple services to integrate vRES such as energy arbitrage, reserves, and frequency control ancillary services. In addition, ESS technologies have a wide range of investment costs (i.e., per power capacity and per energy capacity), losses,

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maximum number of cycles, ramping capacities, and efficiency [10, 11]. This leads to potential applications in power systems such as [12, 13]:

- *Generation services*: load shifting or energy arbitrage, balancing services, frequency response services (e.g., primary, secondary, and tertiary reserve), ramping/load following, black start, firm supply in capacity markets, and vRES curtailment reduction.
- *Transmission and distribution services*: System reliability improvement, congestion management, and deferral upgrades.
- *End-user services*: power quality maintenance, demand reduction, uninterruptable power supply, and back-up power.

The applications of ESS will depend on the power system characteristics and on the type of vRES installed. In this context, one question arises: are the ESS generators, loads, or transmission/distribution assets? The answer to this question leads to a regulatory debate, i.e., whether ESS should be considered as network assets, as generation assets, or as a new separate asset category [14••]. On the one hand, if ESS are considered as generation assets, then unbundling conditions are needed to prevent network businesses (i.e., natural monopolies) from owning and operating ESS in liberalized activities. On the other hand, if ESS are classified as network assets, then they must provide network services only, i.e., avoid participating in liberalized activities. Therefore, given the diverse roles that ESS can play, some authors have even suggested that ESS should be considered as a new type of asset to solve this dilemma [14••, 15]. Moreover, Conejo and Sioshansi [16] analyze the major challenges in designing electricity markets to embrace new technologies that provide opportunities for a more active participation by consumers, including those related to ESS and distributed energy sources. These challenges show the need for new design principles for electricity markets in order to answer questions pertaining to the role of ESS.

In this paper, we review the current policies and proposals for ESS legislation in the United States (US) and the European Union (EU). Moreover, we explicate the main barriers that we have identified for an integrated ESS deployment. We finally discuss how legislation and regulation should be adapted to shed light on the role of ESS to enable ESS to provide its whole value to power systems. Otherwise, regulation, including the design of electricity markets, could place significant restrictions for the correct development of ESS.

ESS Policies in the US

US policies can be divided into state and federal jurisdictions. At the state level in recent years, several states have introduced policies aiming to support the integration of ESS in electricity markets. Some states have included ESS in their energy capacity planning, creating specific programs and even co-funding some projects [12]. However, these policies at the state level show a lack of a common approach in the US for ESS deployment. Each state proposes rules depending on its own priorities to incentivize utility-scale or distributed ESS. This situation explains why ESS have thrived in some states and not in others [17, 18•]. At the FERC jurisdictional level, the PJM system is one successful case in the US for ESS integration [19]. In PJM's wholesale markets, ESS can participate in energy, capacity, and ancillary service markets. Pumped-hydro storage participates in all of these markets; however, battery and flywheel storage technologies participate only in regulation markets (i.e., ancillary services) providing fast regulation service. The main reason for this situation is that battery and flywheel owners have enough economic signals from the reserve markets without the risk of penalization in the capacity market. Nevertheless, this situation could change due to recent federal rules.

On 15 February 2018, the Federal Energy Regulatory Commission (FERC) published the Order (Order 841) [20] to integrate ESS more effectively into wholesale markets in order to enhance competition with proper economic signals. The Order 841 derives from concerns regarding the barriers that ESS may face, which would hinder their participation in organized wholesale electric markets. Three key challenges can be drawn from Order 841: the participation models for ESS in the security-constrained unit commitment, economic evaluation, and regulatory treatment (i.e., ownership).

First, Order 841 establishes that ISOs must represent the physical and operating characteristics of ESS through bidding parameters or other means. FERC includes the following parameters in this bidding format: charging/discharging limits, rates, times, and run time, as well as the state of charge (SoC). These bidding parameters will allow the ISOs to optimize ESS dispatch more efficiently. Moreover, ESS agents should have the option of self-managing the SoC using this bidding format. This option offers to ESS agents the possibility of providing multiple services in the power system. However, Order 841 supports the idea that the ESS is more efficiently dispatched when it is in the hands of the system operator.

Second, the economic evaluation of ESS needs a wider perspective. Therefore, the Order establishes that ESS is eligible to provide all services (e.g., capacity, energy, and ancillary services) that the resource is technically capable of providing. As a result, ESS could find different revenue streams to leverage their investment. Nevertheless, ESS could be still expensive to provide some services in the power system (e.g., as an alternative to peaking plants with fast capabilities). In addition, ESS enable the integration of a high vRES proportion, and they should be properly compensated for these benefits in order to guarantee their cost recovery. Other mechanisms such as forward capacity markets should be adapted to enable the participation of ESS, e.g., allowing them to be aggregated with renewables sources, demand response, or energy efficiency.

Third, FERC does not explicitly mention rules regarding ESS ownership. Recently, FERC issued a policy statement [21] in which the scenario of ESS as a transmission asset is analyzed. This statement mentions that there is no regulatory impediment for ESS to provide transmission and generation services at the same time. However, several concerns arise in this scenario. For instance, RTO/ISO independence and double recovery of costs are among the main concerns. In order to tackle these concerns, the California Public Utilities Commission (CPUC) issued a decision on multiple-use application issues [22], which provides direction to the utilities on how to promote the ability of ESS to realize their full economic value when they can provide multiple benefits and services to the electricity system. This decision defines 11 rules to determine the evaluation of these multiple-use ESS applications, as well as definitions of service domains, reliability services, and non-reliability services. Nevertheless, this decision still leaves some open issues such as tariffs, aggregation with distributed energy resources, appropriate metering, measurement, and accounting methodologies. Therefore, the discussion on ESS ownership versus the provision of multiple services is still an open topic, and its resolution will condition future ESS deployments in the US.

Barriers for ESS Development in the US

The authors in [23] review some relevant regulatory barriers affecting storage in the US. This review mentions, among the major barriers to the deployment of energy storage, the lack of clarity surrounding the functional classification of energy storage and its provision of simultaneous services across different sectors, viz., production (i.e., generation), transmission, and distribution. As mentioned above, energy storage resources are technically capable of providing services in each of these three classifications. However, regulatory restrictions along with accounting practices and requirements (and the lack of clarity and transparency in these practices and requirements) are considered to prevent a utility or developer from obtaining revenue with a resource providing service under multiple classifications. In addition, each US market has its own system characteristics, stakeholders, regulations, and market designs, which makes it more difficult to study a business case for ESS because the revenue streams are difficult to predict for future investments.

ESS Policies in the EU

At the European Union level, the electricity industry is regulated by The Electricity Directive—Directive 2009/72/EC and The Renewable Energy Directive—Directive 2009/28/EC. These Directives aim for the completion of the Target Model for the Single Energy Market for Europe. There are many references to electricity storage in the existing regulation. However, further details are required. For instance, The Electricity Directive includes a list of definitions regarding power generation, transmission, distribution, and supply terms. Nevertheless, the concept of ESS is not mentioned in the document. The Directive fails to include ESS as a separate component in the electricity sector structure. As result, ESS is generally treated as a generation asset in Member States [24].

This situation is changing in the Commission's "Clean Energy for All Europeans" proposals [25] and, particularly, with an improved regulatory framework proposed under the Market Design Initiative (MDI). For instance, the following definition of energy storage is included: "Energy storage in the electricity system would be defined as the act of deferring an amount of the energy that was generated to the moment of use, either as final energy or converted into another energy carrier." However, ESS is not established as a separate component of the power system with its own characteristics, and this could restrict the potential of ESS [26]. The proposal also removes discriminatory network tariffs (e.g., double grid fees) that unnecessarily disadvantage ESS.

The development and operation of storage facilities are promoted in the new MDI as a commercial activity to be performed by market participants rather than regulated entities. TSOs and DSOs should not own, manage, or operate ESS facilities. In exceptional cases, the system operators could be allowed to invest in an ESS facility under regulatory approval and supervision only if other market parties are not interested in providing a specific ESS service. According to the EU [27•], in these cases, the regulatory authorities should regularly reassess the potential interest of market parties to be involved in such activity.

In February 2017, alongside the Second State of the Energy Union report, the European Commission published a Staff Working Document entitled: "Energy storage – the role of electricity" [27•]. This document outlines the role of energy storage in relation to electricity, presents the advantages of different technologies and innovative solutions in different contexts, and discusses possible policy approaches. In summary, the development and financing of ESS should depend on the following principles:

- ESS should be developed to the extent that the overall costs of the new power system are lower with storage than without storage.
- In relation to the electricity grid, ESS should be rewarded for the services provided with alternative suppliers for those services, either demand response or flexible generation.

- The supporting role of ESS in integrating vRES should be rewarded for its contribution to improved energy security and electricity sector decarbonization. In addition, the avoided costs of vRES curtailment and the carbon reductions could also support the business case for large-scale ESS.
- If either a consumer or a generator wants to integrate an ESS at its current facilities, then this should not lead to less favorable treatment (e.g., discriminatory grid access, or paying at the same time grid fees as both consumer and producer) either in terms of obligations or in terms of eventual support that it receives in the power system.

The EU is addressing these principles for ESS by promoting innovation in key technologies and developing suitable market rules. Technological innovation in storage falls under the *Horizon 2020 programme* [28] and the *Strategic Energy Technology Plan* [29]. Moreover, large storage projects above 225 MW are included in the selection process for the EU's projects of common interest (PCI).

Barriers for ESS Development in the EU

In the previous section, we have shown some of the barriers that ESS face in the EU due to the ownership dilemma. In this section, we discuss the other facet of the problem: day-ahead market (DAM) bidding formats. ESS can currently participate in DAMs as generation assets. The European Price Coupling of Regions (PCR) [30, 31] offers different types of bidding formats. These bidding formats can be divided into two groups: complex orders and block orders. The latter category is, a priori, the best fit for ESS bidding into the DAM because it allows the ESS operators to submit a *linked block order*, which consists in an off-peak purchase order (i.e., to charge the ESS) linked to a block order that sells electricity during peak hours (i.e., thus discharging the ESS) [14••, 32]. Therefore, the ESS operator can be certain that the device will not be committed for an infeasible operation point. Furthermore, the money spent in the purchase order must be compensated by the profit earned by the selling order. Despite these apparent advantages, this bidding format does not guarantee the most efficient operation of ESS because ESS operators must predefine which hours will be in the selling order (i.e., peak hours) and which in the purchase order (i.e., off-peak hours). This situation exposes the ESS operator to a price risk, thereby making the revenue streams difficult to predict (as in the US case). In addition, ESS operators who participate in the DAM are not allowed to provide network services. Therefore, ESS operators could face difficulties recovering their investments, which could restrain the ESS deployment at EU level. Contracts for differences (CfD) could be an option to hedge this risk. However, in the UK for example, the ESS is used only to store electricity generated by a CfD-awarded generating facility, which limits the ESS participation as an independent entity in the CfD [33]. All of these situations show examples of regulatory barriers that hamper ESS investment in the EU.

Discussion

From the regulatory point of view and according to the reviewed legislation in earlier sections, it is possible to summarize the key topics for ESS in two: (i) the regulation of the ownership of storage to avoid an outcome with insufficient unbundling, which may hamper market operations, among other considerations and (ii) the need to rethink market design across timeframes (i.e., capacity, day-ahead, intraday, and real-time markets).

Regarding ESS ownership, unbundling principles forbid its ownership by regulated entities. Nevertheless, in the particular case of ESS, this leads to an inefficient realization of the full ESS potential. By contrast, allowing ESS ownership by regulated entities (i.e., TSOs or DSOs) may enable ESS to provide network services; however, it may create a conflict of interest or market inefficiencies due to the monopoly nature of these entities. Therefore, the crucial regulatory challenge is to guarantee that ESS can provide market and network services as well as market efficiency. This efficiency of market mechanisms could be made possible by eliminating cross subsidies between regulated and market parties and avoiding conflicts of interest. As a possible solution, some authors [26, 32] have proposed allowing grid operators to procure system flexibility services from third-party ESS operators in the market. The creation of a proper market for ESS services could mitigate concerns about ESS ownership. In addition, more competition could be introduced to this market if small players are allowed to participate, individually or through aggregation. If properly implemented, then this reform could also address issues related to the provision of cost- and market-based services. A third-party ESS provider has advantages because TSOs or DSOs could use competitive offers to obtain network services and, through their bids, incorporate potential revenues from market-based services that are unrelated to network services. Therefore, the ESS owner could deliver network services and participate in the markets (e.g., DAM, intraday, or balancing), every time the TSO or DSO has not contracted the ESS services, and incomes (or penalizations) from the operation of the ESS in the wholesale market would belong to the third party and liberalized owner of the ESS. In contrast to a third-party ESS provider, Sioshansi [34] has proposed a solution where storage-capacity rights are auctioned to third parties that use their rights for cost- or market-based services. As in the third-party ESS provider proposal, the benefits that the storage asset provides are separated from the regulatory treatment of those benefits (e.g., either competitively priced or unpriced), guaranteeing that ESS assets can recover their cost. A special characteristic of storage-capacity rights is that they are agnostic to who operates the storage capacity auction. Therefore, even an ISO may be able to operate the auction without threatening its market independence. The authors in [13] show the increase in the commercial value derived from ESS provision of network and market services. This is possible only in a regulatory framework that balances synergies and conflicts among the provision of different types of services while maximizing ESS revenues.

Regarding market design, it was shown that ESS are eligible to participate in DAMs of both the EU and the US. However, the inter-temporal constraints of ESS provide challenges to guarantee that the ESS is scheduled within their operational parameters in the most efficient way. The bidding options for ESS in DAMs should give market signals for flexibility in the power system. On the one hand, the EU approach does not guarantee the most efficient operation of ESS because the linked block order limits the charging/discharging hours to some predefined values that cannot be optimized in the DAM in order to increase total system welfare. On the other hand, this is different from the FERC approach, which suggests that ISOs could more efficiently optimize their dispatch. However, the FERC approach is suitable only if there are no market failures (e.g., lack of competition) and market rules are fulfilled; otherwise, it could hamper ESS development if there are market failures such that the efficient dispatch, performed by the ISO, does not allow ESS to obtain sufficient revenues on their investments. The lack of market signals makes it challenging for an ESS investor to make a business case for deployment. In fact, the authors in [35] have shown in the EU context that the revenues of ESS performing arbitrage in the DAM horizon are far from ensuring profitability in different markets. The authors of [15] state: "when the electricity market is well conceived, it remunerates correctly the services valuable to the electric system (e.g., capacity, energy, congestion management, real time balancing and frequency regulation) and it internalizes externalities such as congestion in nodal or zonal pricing of electricity." In conclusion, current DAM rules in the US and the EU should be adapted to enable ESS participation in both network services and liberalized activities in order to obtain an optimal integration of these resources in power systems.

Outside the US and the EU, an example from Chile may provide a pathway for ESS in terms of regulation and new opportunities. The Chilean case is interesting because, for the first time in that country, the law 20.936(2016) [36] explicitly defined ESS as a power system asset, which is different from the existing definitions of generation and transmission assets. This opens the door to a wider possibility for integrating ESS properly with different kinds of services. Although the current definition allows ESS to participate only in the energy market, new regulation is under development to define the participation of this new asset in ancillary and network services. This could be a litmus test for future regulatory developments integrating ESS into power systems combining both liberalized market and network services. Both the US and EU market structures could benefit from this approach, which addresses the two key issues for ESS mentioned at the beginning of this discussion: *ownership* and *market design*. As a new asset, ESS should reduce the risk of insufficient unbundling for its owners in the market because they should be third party apart from generation and transmission activities. In addition, new market rules can be developed for this new asset, especially for situations when it provides part of its capacity for a network service (e.g., congestion management) and the remaining part in the liberalized markets (e.g., DAM, intraday, balancing, or capacity markets). Apart from the new asset approach, there have been discussions that focus on services that can be provided rather than the asset definition [37]. This approach also aims to unlock the ownership dilemma and market design issue by stacking multiple services that can lever ESS investment. In addition, focusing on services might provide other technological solutions such as aggregation of distributed generation, demand response, and distributed ESS. No matter the approach (i.e., either a new asset or new services), in both the US and EU frameworks, the major challenge is making new rules efficient enough that ESS owners have the right incentives to participate in both kinds of services while they recover the ESS investment without support mechanisms or subsidies.

Finally, it is important to mention that technology costs are currently the greatest barrier preventing further development of ESS. Despite recent cost reductions, ESS are still far from being treated as an economically competitive technology, although there are exceptions for particular uses, such as frequency regulation in PJM [19], integration of renewables in Australia [9], grid-balancing services in the UK [38], and transmission congestion management in Italy [39]. As a consequence, some R&D is still needed, and, as it is usually the case with immature technologies.

Conclusions

This paper has summarized the regulatory debates regarding ESS in the US and the EU. In particular, the debate surrounding ESS ownership and market design for different time frames is highlighted. Despite the latest proposals, there are regulatory aspects (e.g., ancillary services, capacity, and energy mechanisms) that also need to be upgraded to guarantee that market products enable ESS to provide power system needs such as flexibility. Definitions of a new type of asset or the third-party ESS provider designation are options to overcome the current barriers without hindering their market design principles.

Finally, some ESS technologies, such as batteries and power-to-gas, are still in a pathway to reduce manufacturing cost or even under development. Therefore, different rules are needed to support optimal investment in different ESS technologies. These investments should be based on market profits rather than on subsidies (i.e., to avoid market distortions) and should be enabled by contracted services that allow ESS to add value in power system operation, such as balancing services to the power system, congestion management, prevention of curtailed vRES, and integration of vRES.

Compliance with Ethical Standards

Conflict of Interest Diego A. Tejada-Arango, Afzal S. Siddiqui, and Sonja Wogrin each declare no potential conflicts of interest. Efraim Centeno reports project funding from Endesa.

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- •• Of major importance

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