Innovative business models to deliver critical system services through battery-based energy storage

Innovative Geschäftsmodelle zur Bereitstellung kritischer Systemdienstleistungen durch batteriegestützte Energiespeicherung

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Abstract — The paper describes the multiple values of battery-based energy storage systems to deliver critical services to all the market players along the electricity system value chain. After the rapid scaling of batteries in consumer electronics battery-based energy storage systems have become the dominant energy storage technology, which: 1) serves as an alternative to traditional generation – replaces gas fired peaker power plants and smooths power output from renewable energy sources, provides fast frequency response and voltage control; 2) eases transmission and distribution constraints subject to the limitations provided in European law; and 3) provides critical power, multiple balancing and energy management services as well as demand response for end customers. The latter is accompanied by innovative models for assessment of the costs and benefits and the overall value storage brings. (***Abstract***)

***Zusammenfassung* —** Der Beitrag beschreibt die vielfältigen Vorteile batteriegestützter Energiespeichersysteme, die allen Marktteilnehmern entlang der Wertschöpfungskette des Elektrizitätssystems wichtige Dienste leisten. Nach der raschen Verbreitung von Batterien in der Unterhaltungselektronik haben sich batteriegestützte Energiespeichersysteme zur dominierenden Energiespeichertechnologie entwickelt, die: 1) als Alternative zur herkömmlichen Stromerzeugung dienen, d. h. gasbefeuerte Spitzenkraftwerke ersetzen und die Stromerzeugung aus erneuerbaren Energiequellen glätten sowie eine schnelle Frequenz- und Spannungsregelung ermöglichen; 2) die Übertragungs- und Verteilungsbeschränkungen vorbehaltlich der in der europäischen Gesetzgebung vorgesehenen Beschränkungen abmildern; und 3) kritische Energie, mehrere Ausgleichs- und Energiemanagementdienste sowie eine Nachfrageregelung für Endkunden bereitstellen. Letzteres wird von innovativen Modellen zur Bewertung der Kosten und Vorteile und des Gesamtwerts der Speicherung begleitet.

I. Introduction

Accelerated deployment of new and larger capacities for electricity generation from renewable energy sources (RES), associated with an increase in their share in final energy consumption, is one of the foundations for the implementation of the Energy Transition from traditional fossil fuel energy production to a low-emission and carbon-neutral economy. Alongside it, technologies for electricity storage and for the management of electricity systems are coming to the fore in the context of decentralised electricity production and consumption and the intermittent nature of RES generation.

The technologies driving the unprecedented energy revolution have in turn undergone unprecedented transformation and evolution in terms of maturity, performance, efficiency, safety and, above all, the economic viability of investment and operating costs. The evolution of technology is closely linked to the evolution of socio-economic relations and strategic business and investment models in the “new electricity system”, requiring an innovative approach in every aspect of project development.

II. Study of business cases for the application of energy storage solutions

This paper explores the technological capability of electricity storage solutions to provide critical services to specific elements along the value chain of the electricity system.

Leading experts are coalescing around the classification proposed by the experts from the International Renewable Energy Agency (IRENA), based on the classifications used by the US Department of Energy State Department, which define the following categories of services provided by electricity storage installations:

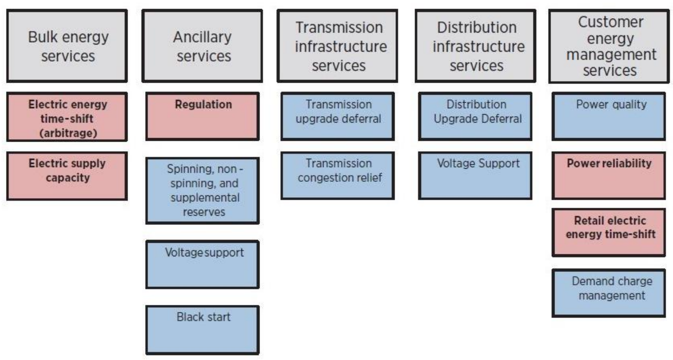

Fig.1: Scope and definition of services provided by electricity storage installations (IRENA, 2015, p.11) [1]

This paper is exploring the first three sets of services and the basics of the associated business models.

A. *Provision of electricity system balancing services, including availability, and balancing energy*

Balancing is a key service for maintaining the balance between generation and consumption in the electricity system.

According to the generally accepted definition in the regulations of the European institutions, "balancing" means "all actions and processes, in all timelines, through which transmission system operators ensure, in an ongoing manner, maintenance of the system frequency within a predefined stability range and compliance with the amount of reserves needed with respect to the required quality" (Article 2(10) of Regulation (EU) 2019/943 of the European parliament and of the Council of 5 June 2019 on the internal market for electricity (recast); Article 2(1) of Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing). In the balancing process, the relevant service provider gives or receives (consumes) "balancing energy", which is broadly defined as "energy used by transmission system operators to carry out balancing" (Art.2(11) of Regulation (EU) 2019/943). The definition in Article 2(4) of Regulation (EU) 2017/2195 also adds that this energy is "supplied by a balancing service provider" - "a market participant providing either or both balancing energy and balancing capacity to transmission system operators" (Article 2(12) of Regulation (EU) 2019/943). In turn, "balancing capacity" means "a volume of capacity that a balancing service provider has agreed to hold and in respect towhich the balancing service provider has agreed to submit bidsfor a corresponding volume of balancing energy to the transmission system operator for the duration of the contract" (Art.2, Paragraph 13 of Regulation (EU) 2019 / 943).

In view of their importance, balancing services and related transactions are normally transacted in a separate market called the “balancing market”. According to the definition set out in Regulation (EU) 2017/2195, a "balancing market" is " the entirety of institutional, commercial and operational arrangements that establish market-based management of balancing" (Article 2(2)). The person responsible for the balancing of the electricity system is the relevant independent transmission system operator and this is normally the person who organizes the balancing market.

The balancing market operates by activating balancing bids (or requests), which are provided by balancing serviceproviders – the entities that have made part of their available capacity available to the relevant independent transmission operator, normally against payment of a price for doing so (typically in MWh). When an event occurs in the electricity system that disrupts the balance between consumption andgeneration – for example, the system runs into a power shortage due to a sudden and unpredicted increase in consumption, the independent transmission operator activates a balancing service provider which, within a short operatingtime, supplies the necessary balancing electricity and thus restores the balance between consumption and generation of electricity so that the system can meet the higher electricity demand and produce the required balancing power. In theopposite case, when an event occurs in the system that again disturbs the balance between consumption and production of electricity, for example - an accident at a large industrial consumer, due to which it temporarily suspends operations, thesystem receives an excess of electricity, which can lead to disruption and damage to equipment and even create a danger to life and health of people, if not contained. Then, the independent transmission operator reactivates the bid from a balancing energy supplier that has the technical capability to reduce its generation to the amount necessary to ensure balance in the electricity system and/or to increase its consumption to such levels.

Generally, the providers of balancing services – balancing energy and available capacity for participation in the balancing market are conventional power plants (condensing and hydroelectric power plants, including pumped storage hydroelectric power plants – PSHPPs) and sufficiently large industrial consumers (users) of electricity that meet certain technical requirements for demand response upon receipt of a dispatch order to activate them as a balancing energy provider. The participation of industrial energy consumers is foreseen in the framework of the so-called demand response service. According to the definition of "demand response" provided by the European legislator in Article 2(20) of 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 (recast), the latter means "change of electricity load by final customers from their normal or current consumption patterns in response to market signals, including in response to time-variable electricity prices or incentive payments, or in response to the acceptance of the final customer's bid to sell demand reduction or increase at a price in an organised market as defined in point (4) of Article 2 of Commission Implementing Regulation (EU) No 1348/2014 (17), whether alone or through aggregation”. Regulation (EU) 2019/943 refers to precisely this definition (Article 2(44)).

The European electricity market acts adopted in 2019 strengthen the regulatory and legal framework for the so-called aggregation and aggregators as participants and providers of balancing services. Thus, in practice, a number of smaller end-customer sites and/or generators can participate together (i.e. their dispatchable capacities are "aggregated") to provide dispatchable power and balancing energy. According to the adopted definition, "aggregation" means " a function performed by a natural or legal person who combines multiple customer loads or generated electricity for sale, purchase or auction in any electricity market" (as per Article 2(18) of Directive (EU) 2019/944). Regulation (EU) 2019/943 refers precisely to this definition (Art.2, (43)). The European legislator has also created a definition in Article 2(19) of Directive (EU) 2019/944 for “independent aggregator”: “a market participant engaged in aggregation who is not affiliated to the customer's supplier”. In practice, this creates the legal possibility for the aggregation service to be provided to the Independent Transmission Operator by a third party other than the current electricity supplier for that customer and eliminates a potentiallimitation for this function to be performed solely by the supplier, as well as resulting in the customer being unable to provide its dispatchable loads to the electricity system if its electricity supplier is unable to perform the aggregator function.

The “price arbitrage” formulated by the experts of IRENA refers to the specific situation of balancing energy price formation. Typically, electricity markets set extremely high prices for balancing energy in times of shortage and extremely low, even negative, prices for balancing energy in times of surplus. Under these circumstances, a balancing energy supplier, such as an energy storage facility, could use “cheap”" energy at the balancing market surplus price and sell it back into the system at the balancing energy deficit price. The difference that results between the price at which it received the energy at the surplus price and fed it back into the system atthe balancing energy deficit price is called “price arbitrage”.

This category also includes atypical balancing services - the installation of an energy storage facility at the site of a renewable electricity generator and the use of the energy storage facility as a peaking power plant. In the former case, the facility has a common grid interconnection with the renewable energy generation facility (wind and/or solar), supporting the predictability of generation and providing some degree of independence from the fluctuation and intermittency of the primary energy source, wind and/or solar. In effect, the energy storage facility 'balances' the renewable generator -when there are fluctuations in generation, for example when a cloud passes over the solar installation for a short period of time, then the energy storage facility can inject energy tocompensate for the lack or reduced generation at that time. In this way, the renewable energy generator will meet the generation forecast to the Independent Transmission Operator and will not put the Independent Transmission Operator in the position of having to activate a balancing energy providerand/or ancillary services to compensate for a shortfall in energyon the grid.

In the second case, the energy storage facility is a "peaking" (peak) power plant. Generally, these are to be the last plants activated to provide generation balance in the power system to meet so-called "peak" load - the hourly ranges of increased demand (consumption) for electricity. The specificity of this type of plants is that they do not operate as base plants - 24/7 - twenty-four hours, seven days a week at the same constant load (usually maximum - i.e. full power), but only during the specific hours when the peak demand needs to be covered. Thelatter raises the question of what would be the most economicaland energy-efficient mode of operation, with the leastgreenhouse gas emissions, to be able to provide the balance of generation in the power system, given that their usability is reduced, and they need to be available to the operator - i.e. to be on standby and in parallel to the power system quickly enough. Typically, these are 'gas plants' - power plants whose primary energy source is natural gas that have the technological capability to start up quickly and reach maximumoutput in less than ten (10) minutes. The current gas crisis necessitates reassessment of the use of gas-fired power plants.

In view of the above, the necessary statutory and regulatory prerequisites are in place for such an energy storage facility to perform the function of a balancing energy provider by providing dispatchable power and balancing energy, fully replacing conventional electricity generators. For this purpose, it shall fulfil the requirements to be approved and registered as a balancing energy supplier by the relevant independent transmission operator in accordance with the rules for the organisation and administration of the relevant balancing market or market association.

B. Ancillary services

These are all services required for the reliable and safe operation of the power system. They are closely related to balancing and can be defined as balancing services. Considering the existence of a large number of separate services and the different structures of electricity sectors around the world, IRENA experts have separated them into a separate group for the purpose of studying applications for energy storage systems and facilities within the electricity sector.

According to Article 2(48) of Directive (EU) 2019/944, “ancillary service” means “a service necessary for theoperation of a transmission or distribution system, including balancing and non-frequency ancillary services, but not including congestion management”. The following paragraph 49 of the same Directive complements the concepts with a definition of “non-frequency ancillary service” which means “aservice used by a transmission system operator or distribution system operator for steady state voltage control, fast reactive current injections, inertia for local grid stability, short-circuit current, black start capability and island operation capability”.

The above two definitions serve to distinguish between the two main groups of ancillary services - those for frequency control (regulation) and those for voltage regulation. The main ancillary services for frequency regulation are: primary frequency regulation, secondary frequency regulation (automatic and manual) and back-up, “black start” (the ability to start the power output without the aid of an external source). The main ancillary voltage regulation services are related to the supply ('injection') of reactive power. Typically, the ancillary services are provided by conventional energy sources, i.e. thermal (condensing) and hydroelectric power plants, and the independent transmission operator determines the technical parameters of these services and their type, and “obliges” the operators of the respective plants to “reserve” a certain available capacity of the total installed capacity of the respective plant (generating facility) to be available when the system needs to activate it. Thus, in practice, certain power plants using conventional energy sources are not allowed to realise all their available electricity capacity on the electricity market (i.e. to sell all the electricity they can produce) because the operator has “blocked” a certain, albeit seemingly small, amount of capacity for the system's needs – so that the ancillary services can be provided (activated) at the right time. An important aspect is that, in order to be able to provide the ancillary services in question, the relevant generation sites must be “in operation” and, above all, should be in parallel with the electricity system, not exceeding their specified load level. This raises another issue in the context of the Energy Transition - that of managing the electricity system efficiently while emitting the lowest level of greenhouse gas emissions. When ancillary services are provided by conventional condensing power plants whose primary fuel is coal (or natural gas to a lesser extent), this does not result in greenhouse gas (GHG) emission reductions, while it is questionable whether they operate at their best level of efficiency and effectiveness (with the highest efficiency – coefficient of performance), provided that they do not operate entirely in base load (plant) mode.

A “spinning reserve”, according to the Energy Storage Association (USA) blog, now part of the American CleanPower Association, is “Generation capacity that is on-line but unloaded and that can respond within 10 minutes to compensate for generation or transmission outages. “Frequency-responsive” spinning reserve responds within 10 seconds to maintain system frequency. Spinning reserves are the first type used when shortfalls occur.” [2] (Source: Energy Storage Association, now American Clean Power Association). In Europe, the new regulatory framework on balancing refines the services and their definitions, with the consequence that 'spinning reserve' is dropped as a stand-alone service for the reason that it effectively covers all generating capacities that are in parallel to the power system at any given time and have the technical capability to support the balancing of the power system - these are 'the adjustable active power ranges of all synchronous generating capacities that can be used. “Spinning reserve” is part of the definition of ancillary services under the Bulgarian Energy Act - item 14 of §1 of the Additional Provisions until the 2021 version of this provision - by the amendments to the Energy Act promulgated in Official Gazette no. 9 of 2021, in force since 2.02.2021, “spinning reserve” is removed from the definition of ancillary services.

In view of the above, the necessary statutory and regulatory prerequisites are in place for such an energy storage facility to act as a provider of ancillary services for balancing the electricity system by providing available power and regulation range to the transmission system operator and/or the distribution system operators (in case the statutory and regulatory framework allows such services to also be provided to the distribution system operators). "Green policies", as an umbrella term for all policies to reduce greenhouse gas emissions, highlight a certain advantage for balancing the electricity system, including the provision of additionalservices precisely through energy storage facilities, in view of the fact that they are almost always in "standby" mode and in parallel to the electricity system, and this does not involve the release of GHG emissions, nor in cases where they are activated to balance the system, as is the case for systembalancing.

C. Electricity transmission services

“Transmission” of electricity means, as defined in Article 2(34) of Directive (EU) 2019/944, “the transport of electricity on the extra high-voltage and high-voltage interconnected system with a view to its delivery to final customers or to distributors, but does not include supply”. In turn, this interconnected system of ultra-high and high voltage consists of substations, transmission lines, installations and other facilities in a complex configuration to carry out the transmission of electricity. Transmission activities also includethe reliable, safe operation of this system, in compliance with all applicable safety and environmental regulations and standards, and the forward-looking planning of the necessary investments to ensure the long-term capacity of the network to meet the forecast development of electricity consumption ('demand', which is the term for the specific commodity of electricity) and security of supply within it.

In view of this, whenever the need arises (e.g. in the case of investment in new industrial plants and factories, which is associated with an increase in electricity consumption, a corresponding increase in the transmission capacity of the grid arises), the respective owner and/or operator of this system shall build new power lines and/or substations and associated installations and facilities. Depending on the specific case, instead of building a new substation, for example, the respective owner and/or operator of the transmission assets may build an energy storage facility and use it to ensure the secure supply of energy within the electricity system. Another example where an energy storage facility facilitates the deferral and even full replacement of investment in traditional electricity transmission infrastructure is for the construction ofa new interconnector (interconnection between neighbouring electricity systems) and/or the increase of the transmissioncapacity of an existing such interconnector.

The energy storage facility can also assist the grid operator in managing grid congestion for the purpose of avoiding and/or alleviating so-called bottlenecks in the grid. Grid bottlenecks are the result of grid congestion. The European legislator has defined “congestion” in Article 2(4) of Regulation (EU) 2019/943 as “a situation in which all requests from market participants to trade between network areas cannot be accommodated because they would significantly affect the physical flows on network elements which cannot accommodate those flows”. I.e. in a particular section of the grid, the transmission capacity turns out to be lower than the electrical power that needs to be transmitted through that section – despite the full compliance with all criteria, rules and security standards. Such sections create so-called “bottlenecks” which may lead to the need to limit the generation and/or consumption of electricity by certain electricity users if not “overcome”.

In establishing an economic and business model for the construction of an energy storage facility, the ownership of the asset and its operating regime should take into account the restriction for independent transmission operators to "own, develop, manage or operate energy storage facilities" - Article 54 of Directive (EU) 2019/944, unless it has the status of "fully integrated network components". The energy storage facility is then considered as an integral part of the assets of the transmission system and is only used for the purpose of ensuring the secure and reliable operation of the transmission system. In this case, where the owner of the asset is the Independent Transmission Operator, the Independent Transmission Operator may not use the energy storage facility for balancing or congestion management on the electricity system. In order to be used for congestion management and the elimination and/or alleviation of bottlenecks in the network, the owner and operator of the asset should be a third party, distinct and independent from the relevant independent transmission operator.

In view of the above, the necessary legal and regulatory prerequisites are in place for such an energy storage facility to fully replace the construction of a new transmission line, substation and other assets, or where it is necessary to carry out the modernisation, rehabilitation, expansion, renewal of individual elements and sections of the electricity grid, subject to the ownership restrictions introduced in European legislation and the purpose of the so-called "fully integrated network components". There are no legal and regulatory obstacles to storage facilities helping to manage congestion and overcome bottlenecks in the network - again in strict compliance with the European legislator's requirements for ownership of the facility and the restriction that “fully integrated network components” cannot be used to manage congestion. In the United States of America (USA), it is precisely such energy storage facilities that are often used to limit and/or completely eliminate cases where renewable energy (RE) generators need to be curtailed and/or redispatched in order to avoid congestion on the electricity system or when redispatching capacity in so-called "bottlenecks".

III. CONCLUSION

The dynamics of the development of renewable energy technologies and electrochemical energy storage present challenges and opportunities along the electricity value chain. The technological capability to provide the most critical services for the entirety of the electricity system [3], provides electricity storage solutions with a leading role in the Energy Transition and gives rise to new and innovative business models.

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