ELECTRICITY STORAGE: HOW TO ENABLE ITS DEPLOYMENT?

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ABSTRACT

Electricity storage technology is one of the components that can provide flexibility to the electricity system and could become an important tool in the future. As new storage technologies are being developed, new technical, economical and regulatory challenges need to be overcome in order to enable the large-scale deployment of electricity storage.

INTRODUCTION

Electricity consumption has hiked in recent years, with global energy demand forecast to increase by 56% between 2010 and 2040 [1]. New technologies, such as wind and solar, have emerged to capture power from variable renewable sources. But that's not enough, because the sun only shines for certain hours of the day and wind can only be forecast a few days ahead.

Electricity storage is technology's latest breakthrough to help resolve the electricity paradigm. By storing energy, grid operators can distribute electricity in line with consumption needs in cities, towns, factories, homes, *etc*. and no longer only when the weather makes it available.

Electricity storage is one important technology that can provide flexibility to the electricity system and empower the EU along with other countries to achieve a green transition. According to the European Commission's paper on the future role and challenges of Energy Storage, energy storage will "*play a key role in enabling the EU to develop a low-carbon electricity system*".

Electrical storage consists of a wide range of technologies. In its white paper, IEC classifies Electrical Energy Storage systems according to the form of energy used. These systems are classified into five categories:

- mechanical as flywheels, air compressed storage and pumped-storage hydropower plants,
- electrochemical as battery energy storage systems (BESS),
- chemical as hydrogen storage,
- electrical as super-capacitors,
- or thermal, as heat storage.

In this paper, the term "Electrical energy storage" refers to energy storage systems mostly used within distribution networks; this includes battery energy storage systems or flywheels, and excludes pumped hydro, chemical or thermal storage.

The deployment of these storage technologies has raised new technical, economic and regulatory issues. This article presents the most critical and structuring concerns for the development of storage technology and the possible solutions based on the French regulator's analysis and hands-on experience from Alstom.

ELECTRICITY STORAGE FACES NEW TECHNICAL AND EVOLVING CHALLENGES

Electrical energy storage market trend

The electrical energy storage market has made significant strides. It has already doubled in worldwide storage capacity from 370 MW in 2011 to 730 MW in 2013 [2]. A 2012 report from Pike Research predicts that by 2020, almost 70% of the energy storage market will be driven by the integration of renewables into energy grids. The report expects the total capacity of electrical energy storage on the grid to reach 10,000 MW by 2020. In 2014, this trend is confirmed by Bloomberg [3] which expects 500 MW of electrical energy storage announced by the year's end.

There are three major challenges related to the widespread deployment of electrical energy storage:

- Cost competitiveness of energy storage technology (including manufacturing and grid integration): Achievement of this goal requires attention to factors such as life-cycle cost and performance (round-trip efficiency, energy density, cycle life) for energy storage technology as deployed.
- Technical challenges: Validation of the safety, reliability, and performance of energy storage is essential for user confidence.
- Non-discriminatory regulatory and market environment: Value propositions for grid storage require a level playing field market between the different service providers (storage, demand

response, generation, grid reinforcement, *etc*.).

Storage systems are becoming cost competitive

Today, the cost of some storage systems has declined to economically attractive levels; this is the case, in particular, for battery energy storage systems. Driven by the Electrical Vehicle (EV) industry, the price of a typical lithium-ion battery pack has dropped to less than \$600/kWh, while the same pack was worth \$1000/kWh 2 years ago. In the short-term, several studies forecast significant price drops in the next 2 years, while promising battery technologies like metal-air battery already announced prices below \$200/kWh by 2017.

The total cost of storage systems, including all the subsystem components, installation, and integration costs need to be cost competitive with other non-storage options available to electrical utilities. While there is a strong focus on reducing the cost of "storage" components, such as batteries, they only constitute 30% to 40% of the total system cost, thus the focus needs to be on the entire system.

After 1st implementations, technical challenges are about to be tackled

As aforementioned, nearly 1 GW of electrical energy storage capacity is already installed worldwide. These implementations demonstrate the technical feasibility to successfully connect energy storage systems to the grid without disturbing the overall electric system. However, these implementations also show the lack of standards for connecting such systems to the grid. The first application of Alstom's megawatt-scale energy storage system is "Nice Grid", a smart-grid demonstration project located in the south of France, implementing storage at different levels of the distribution network (HV/MV substation, MV/LV transformer, or installed in consumer households).

Connecting Battery Energy Storage Systems (BESS) to the MV network

At present time, no national rules formally exist to connect these new systems to the public grid. In particular, the current national safety standards and conformity certification do not refer to, and are thus irrelevant to storage facilities. In the Nice Grid demonstration project, LV equipment, such as the power conversion system, that connects the battery to the grid, adheres to the requirements in the NF C14-100 standard, while MV equipment, such as MV/LV transformer and switchgears, adhere to those stated in the NF C13-100 standard.

The technical specifications are specified by TSOs and DSOs for the safety, security and proper operation of the public grid, depending on the nature of the asset to be connected to the public grid. Some are specific to generation assets and others to consumption facilities. Moreover, the required technical specifications may also depend on the technology of the asset; specifications for hydropower plants are different from those required for variable renewables for instance.

To invest in any particular asset thus necessitates an understanding of the technical requirements that apply to the equipment. These specifications are of utmost importance for the design of the asset, consequently impacting the economic value and financial structure of the project. Such technical specifications must therefore be known before any investment.

The existing European and national technical requirements do not specifically refer to electricity storage, which may consequently impede its development. The implementation of a technical framework adapted to this technology is crucial to the mass deployment of electricity storage.

Amongst the specifications that would need to evolve, it is important to specify *ex ante* the nature of the expected constructive capacities that are supposed to commit with national and European specifications. This would help avoid a massive equipment review after its deployment, which would not be cost effective.

As mentioned earlier, several different storage technologies exist and are being tested around the world including flywheels and electrochemical batteries. Each has its own specific operating system due to internal technical constraints. Thus, the technical specifications that storage facilities commit to may differ between one particular storage technology to another. The imposed technical specifications may consequently and significantly alter the choice of the storage technology taken by a project holder and should therefore be specified *ex ante*.

Following the deliberation of 12th June 2014 on the development of smart grids in LV, the French energy regulator (Commission de régulation de l'énergie – CRE) suggested the modification of the French legislation to clarify the list of facilities subject to the general technical design and operational requirements, requesting that distribution system operators define rules on the technical design and operational requirements applicable to an electricity storage facility. CRE aims at guaranteeing non-discriminatory rules and considers that any differences in treatment between two users (generators, consumers, storage systems, *etc*.) must be the outcome of objective criteria, relating directly to technical issues in terms of grid safety and security, and quality of operation.

The operation of storage facilities on a day-to-day basis requires a new management approach

While the question of connecting these new systems with the public grid is a first step to pass, a second issue will quickly arise on day-to-day operation. Indeed, the large deployment of distributed electrical energy storage systems raises the question of remote operability, requiring the implementation of vertically integrated energy management systems and appropriate telecommunication tools.

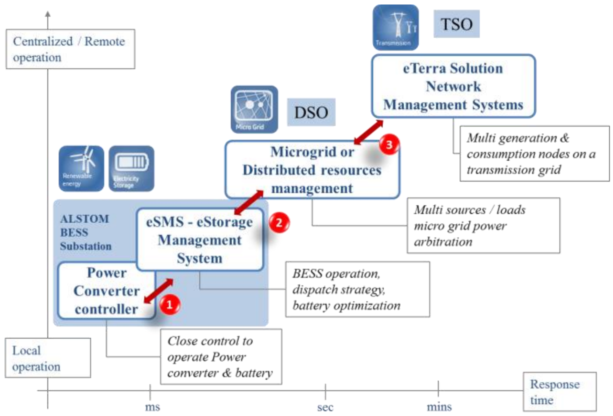

Figure 1 Alstom approach: vertical integration of energy management systems

Nice Grid is a typical demonstration of remotely operating electrical energy storage systems and their appropriate integration within the existing distribution network. Via the implementation of standardized protocols and telecommunications tools, the energy storage management system is directly interfaced with a network management system, which supervises the overall microgrid (including distributed solar energy resources and consumer demand-response management); the network management system itself is interfaced to French DSO – ERDF dispatch center located in Toulon, 150 km from Nice Grid. The battery is then considered as a fully paid up member of the network and a new distributed energy resource, remotely accessible and immediately available for injection or absorption of power according to operator requirements.

A NEW ECONOMIC VALUATION FOR A NEW TECHNOLOGY

Economic valuation of electrical energy storage systems

As mentioned earlier, cost competitiveness has to consider costs of the entire system. Technical factors such as long-term performance (round-trip efficiency, energy density, lifecycle) can significantly impact revenue generation model assumptions and bring uncertainty to these use-case economics that inhibit investments.

To become sustainable, energy storage systems have to take into account the complete lifecycle and adapt to specific service conditions and operator usage. In particular with battery energy storage systems, efficient Energy Storage Management Systems with embedded battery models are essential to ensuring optimum use of a battery fleet to finally extend its lifetime. This optimization aims at limiting maintenance expenditures while preventing the installation from premature ageing.

Electrical energy storage services

Electricity storage can add flexibility to the electric system along with other services. Numerous research studies have been conducted to assess the variety of services that electricity storage provides. As an example, recommendations for a European Energy Storage Technology Development Roadmap towards 2030 have been jointly published in March 2013 by the European Association for Storage of Energy (EASE) and the European Energy Research Alliance (EERA). This roadmap highlights 26 services provided by electricity storage technology to the electric system.

Conventional Generation	Transmission	Distribution	Customers Services
Black start	Participation to the primary frequency control	Capacity support	End-user peak shaving
Arbitrage	Participation to the secondary frequency control	Dynamic, local voltage control	Time-of-use energy cost management
Support to conventional generation	Participation to the tertiary frequency control	Contingency grid support	Particular requirements in power quality
Renewable generation	Improvement of the frequency stability of weak grids	Intentional islanding	Continuity of energy supply
Distibuted Generation flexibility	Investment deferral	Reactive power compensation	Limitation of upstream disturbances
Capacity firming	Participation to angular stability	Distribution power quality	Compensation of the reactive power
Limitation of upstream perturbations		Limitation of upstream perturbations	
Curtailment minimisation			

Table 1 Energy Storage segmentation (Source: EASE-EERA roadmap towards 2030)

It should be noted that electricity storage can provide services for all the stakeholders of the electric system: conventional and renewable producers, transmission and distribution system operators and customers. While one storage facility may not provide all the services characterized by the EASE-EERA study, as it depends on the technology, it is possible to provide several of them.

Current storage demonstrators mainly give technical feedbacks such as connecting constraints but there are few economic feedbacks on the economic value of services. In the context of its own research, Alstom focused on the following.

Used as stand-alone equipment, or coupled to a renewable power plant, energy storage systems address both grid operator and power producer challenges. For grid operator, it handles congestion issues, alleviates overloaded nodes through the network handling peak loads, provides ancillary services like frequency regulation and voltage support, and helps meet seasonal requirements. For the renewable power producer, it provides energy that can be made available very dynamically, allowing him to commit to a production plan and compensate variability; this maximizes the benefit of the renewable energy asset, qualifying the renewable power producer to trade the electricity within wholesale energy markets.

While revenue models for large-scale renewable power plant coupled with energy storage systems still need clarifications, several projects implementing grid-scale energy storage systems around the world have already demonstrated their economic viability.

Investment deferral

Electrical energy storage systems can be connected "alone" to the transmission and distribution grid for:

- Delaying the investment on new transformers, lines and cables.
- Regulating the voltage at a particular point (especially in weak grids). The capacity of injecting active and reactive power allows the BESS to regulate the voltage in both resistive (more often in distribution) and reactive grids (transmission) respectively.

To ensure security of supply while facing constant increase of electricity demand (10-15% per year), Karahmaa [4], a major TSO in Qatar, studied the opportunity to install a battery energy storage system in one of its HV/MV substation subject to peak loads during the summer. This study shows the benefits of electrical energy systems in postponing substation upgrade investments without interrupting network operation.

Frequency control

Frequency control is an increasingly well–established application in the US, with projects already running. In Germany, France and Korea, projects are either commissioned or already under development.

In Germany, one of the most profitable business cases for energy storage is the Primary Control Reserve (PCR). With a minimum bid size of 1MW, battery energy storage systems are now eligible to provide the grid with PCR. This reserve is activated within 30 seconds. In its study, Bloomberg has shown that PCR average annual revenues reached 150k€/MWh/year in 2013 while annualized costs of energy storage were estimated at 91k€/MWh/year.

In France, Alstom is directly involved in "Concept grid", a demonstration project launched by EDF group dedicated to the development of smart electric systems. The experiments by EDF R&D will evaluate the ability of such a system to regulate frequency, and particularly, the adjustment potential of the primary reserve.

Microgrids

IEC defines a microgrid as a group of *"distinct distributed resources such as generators or loads"*, located within close geographical proximity of each other, "*so that they represent a single generator or load to the wider electricity system."*

Microgrids allow end users to become autonomous in their energy provision. By operating their own network of local generators and coordinated loads, microgrid owners/operators can reduce their reliance on the wider electricity grid. By maintaining the ability to island from the wider grid, a microgrid can ensure robust and reliable supply for its enclosed loads, isolated from faults on the wider electricity system. Nice Grid is a typical example of a microgrid connected to the distribution network. It is located on the periphery of France's transmission grid – at the end of a 400 kV line – in a "poorly energized" region that currently produces only 40% of the electricity it consumes. The installed energy storage systems will help, in particular, handle peak loads. The objective of this project is to develop a smart electricity grid that harmoniously integrates a high proportion of solar panels, energy storage batteries and intelligent power meters installed in the homes of volunteer participants.

BESS finally find an important place in microgrids, where it is particularly interesting in those cases with a large penetration of renewable energy sources and critical loads.

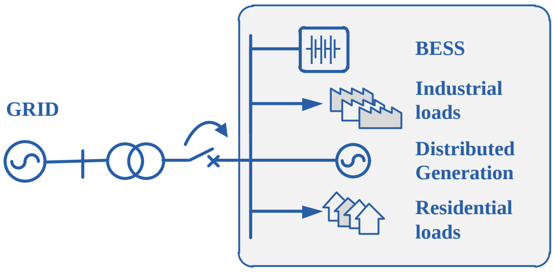

Figure 2 BESS as a part of a microgrid.

THE MANAGEMENT OF STORAGE FACILITIES

An objective, transparent and non-discriminatory access to the grid should be provided to grid users

Public distribution system operators must provide access to the grid in an objective, transparent and non-discriminatory manner. On this basis, two grid users using the grid in the same way must be offered the same access conditions, regardless of their usage of the electricity.

Storage facilities can inject into or extract electricity from the grid. In this respect, to inject energy, they must benefit from similar grid access conditions to those granted to any power plant. In the same way, to extract energy, they must benefit from similar grid access conditions to those granted to any consumer.

CRE considers that the same logic must apply in the context of pricing policy for grid access, with the application of charge when the storage facility extracts energy from the grid and an injection charge when the facility injects energy into the grid. It would not appear justified to treat storage facilities any differently to consumer or power plants connected to public distribution grids. The potential benefits of storage facilities in terms of grid costs savings become evident when the load curve (charging or discharging) can be modulated, reducing constraints on the grid. In France, these benefits are expressed through connection charges and/or grid tariffs.

Clarifying the market players allowed to operate a storage facility

As seen previously, the economic value of the facility depends on the provided service. As for existing electrical equipment, there are three different ways for the concerned equipment to be operated.

Some particular services, which are part of the core activities of DSOs, are provided by grid assets which can only be operated by DSOs, such as tap changers in electric substation. This ensures the safety and proper technical functioning of the electric system. For instance, tap changers in electric substation are operated by DSOs.

Contrarily, other services are open to competition and may thus only be provided by entities that are different from DSOs. DSOs are indeed irrelevant to be in charge of the functioning of various services, and competition between producers and other private market players ensures that the concerned services are provided with optimal economic efficiency. For instance, when storage assets are to deliver electricity to the market, it should be submitted to the economic precedence.

Finally, some services are open to competition, including DSOs. This is the case for additional services, such as the setup of optical fiber along the electricity transmission system. A specific framework, however, needs to be implemented in order to guarantee a level playing field between market players. In this example, RTE has been asked to create a subsidiary division.

The operator that should be allowed to ensure the running of the facility may thus depend on the services provided by storage facilities. Moreover, as there are a variety of services provided by storage facilities each with a different economic value, the question of the entity that runs the asset is complex. Such uncertainty should be clarified to enhance the deployment of storage assets.

Additionally, it is interesting to observe that operators will have to combine multiple roles and responsibilities, including for example:

- Financial owner of the storage assets.
- Land owner where the system is installed.
- Technical Field Operator, for maintenance.
- Service Operator, to pilot the asset and sell the services on markets or mechanisms.

Storage is not only about technical innovation but also about innovative contractual frameworks to cover roles and responsibilities, and transfer value between these actors. Pilot projects or early implementations will also have to investigate these models in order to enable both centralized and decentralized storage.

It should be noted that the three different aspects discussed in this paper – technical specifications, economic value and operating entity – are interlinked: the operating challenge depends on the provided services value, which depends on the storage technology, the geographic location and the voltage connecting level, and thus finally on the technical specifications. Consequently, the implementation of a regulation framework that enables the deployment of electrical storage facilities requires handling those three aspects in parallel.

REFERENCES

[1] IEA, 2013, International Energy Outlook 2013

[2] Presentation DOE – European Utility Week 2013

[3] BNEF, “H2 2014 Global energy storage market outlook”

[4] Kahramaa & Alstom Grid, “BESS and PV panels to meet summer peak in Qatar”, CAUE, Doha, Qatar, 2013.