Electrical energy storage – economics and challenges

Increasing energy storage will allow electricity grids to become more flexible and able to integrate a higher proportion of intermittent renewable energy. However, as *Karim L Anaya* and *Michael G Pollitt* explain, there is still some way to go to iron out the commercial and regulatory issues.

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Electrical energy storage is about storing generated energy for a later use at a specific time that brings more value to the different parties, for example residential and business energy customers, renewable project developers and electric utilities.

The main use of energy storage is to balance power supply and demand over short periods, down to milliseconds. Storage:

- increases consumer savings (by avoiding being charged at peak time periods);
- provides ancillary services (like frequency regulation, which is also translated into lower charges to customers);
- promotes a more efficient and flexible use of the electric network (due to distribution and transmission upgrade deferral); and
- decreases or avoids curtailment at times of excess power production (typically from wind and solar) which allows the use of more renewable energy sources.

The expansion of energy storage brings new challenges to the different parties – not only regulatory but also commercial and technical.

The monetisation of storage can be achieved by removing regulatory barriers in order to allow storage plants to participate in ancillary services, rewarding fast frequency response assets and allowing network operators to own energy storage facilities. Innovative business models are also required in order to facilitate the adoption of distribution system connected storage – as opposed to classic large-scale storage facilities, which are connected to the transmission system.

In relation to technical issues, energy storage methods have not diversified and are still focused on few technologies. Pumped hydropower is the only large-scale and cost-efficient technology, according to the International Renewable Energy Agency, however its economics in the market seem to have weakened. Pumped hydropower's share of total capacity represents about 2% in the US, 3% in China, 5% in Europe and 11% in Japan, according to the International Energy Agency.

It is expected that in the future significant quantities of emergent storage technologies can be commercialised. Policy Exchange has described energy storage as one of the eight greatest technologies of the future for the UK. Three different opportunities are identified – the use of novel battery systems (eg lithium air, sodium and fluoride-based batteries); better energy storage for vehicles (eg innovative batteries and light and non-expensive full cell technology); and the capability to store electricity for the grid in order to support greater intermittent energy generation.

Business models

Energy storage business models relate to the different arrangements that make possible the integration and operation of these devices within the electricity grid. Below are some of the key aspects that such business models need to take into account.

Domain – where to connect? Generation, transmission, distribution or customer level?
Different locations involve different parties and imply specific shares of deregulated and regulated income streams.

Grid integration – stand-alone, integrated systems; centralised or decentralised?
Energy storage can compete and/or complement other types of investment (eg demand side response) to improve flexibility, thus its integration seems to be required.

Ownership – who owns? Electric utilities, third parties?
In some cases, an energy storage system constructed on an owner's land can be transferred to an electric utility upon its completion. An example of this is the Energy Storage System Turn-key Build, Own, Transfer Agreement (ESSBOT) applied by San Diego Gas and Electric, California, in its 2014 All-Source Request for Offer (RFO) – Energy Storage.

Operation – who operates? Electric utilities, third parties? One or multiple operators?
The option of shared operation is also possible by the introduction of a fee paid by the third party operator to the electric utility. UK Power Networks has proposed this approach in its Smarter Network Storage trial project.

Benefits – what is the value of energy storage?
It is important to know the potential income streams that are allowed from both the regulated and competitive market.

Regulation – how is energy storage regulated?
Rules regarding unbundling may limit the participation of electric utilities in the implementation of energy storage projects. Storage has been traditionally thought of as being part of the wholesale power market because it involves

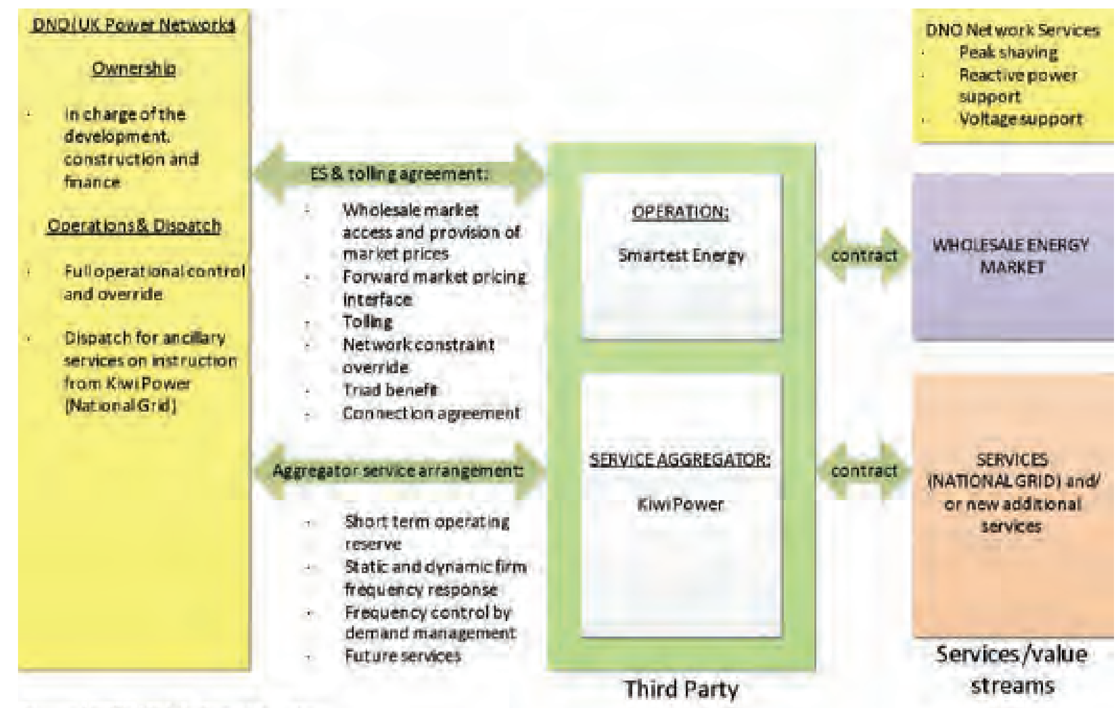

Figure 1. SNS business model – DNO contracted

Source: UK Power Networks, authors' elaboration

buying and selling power. Under network unbundling rules, such as those which exist in the EU, this means that electricity network utilities may be prevented from owning storage facilities (or, more precisely, material quantities of storage).

Another important issue is the treatment of energy storage as a regulated asset. In most EU Member States there is no specific regulation for electricity storage, as there often is for gas storage.

Finally, rules about energy storage procurement also matters. Competitive mechanisms suggested by energy regulators, such as those proposed by the California Public Utilities Commission, propose pre-defined business models. This can help to have more standardised agreements among the involved parties.

Energy that is being imported from the grid incurs one set of grid charges, while energy exported to the grid is also subject to grid charges. Such double charging does not reflect the value of storage to the grid

Smarter Network Storage trial

One example of a business model applied in the UK is Smarter Network Storage (SNS) which is being implemented by UK Power Networks (the largest district network operator (DNO) in the UK with around 8mn customers).

The aim of the project is to demonstrate the technical operation of the multi-purpose application of distribution-connected energy storage using li-ion battery technology (6 MW /10 MWh) at UK Power Networks' Leighton Buzzard 33/11 kV primary substation. Different innovative business models have been explored through a business model consultation from UK Power Networks, allowing the identification of the most viable arrangements. The preferred business model is depicted in **Figure 1**.

In this business model the DNO owns and operates the storage device and allows the involvement of third parties. The third parties are represented by the storage aggregator (Kiwi Power) and the energy supplier (Smartest Energy). The storage aggregator is the intermediary that provides interface with the transmission system operator (National Grid) for the range of ancillary services under trial. Smartest Energy interacts with the wholesale market. Thus, electricity can be imported or exported when required. The energy supplier is allowed to take commercial control of the storage device (when it is not required for network security purposes) in return for a fix fee (tolling).

The introduction of the third party intermediaries requires the DNO to put in place innovative commercial arrangements. One of the main advantages of this model is that this provides greater security of supply in comparison with other alternative models where the DNO does not own the storage device. However, one of the disadvantages is the requirement of placing complex tolling contracts between the DNO and third parties which may be expensive to implement for smaller storage facilities.

Energy storage economics

The economics of particular energy storage technologies depends on cost; as well as the services that energy storage can provide, the avoided costs and environmental impact. The technology selection depends on different factors such as:

- the installed capacity of the generation plant;
- discharge time (from seconds to weeks);
- frequency of discharge and associated lifetime (cycles/ year);
- location within the network (at generator, transmission or distribution level, or end customer); and
- output (thermal, electrical).

In addition, the maturity of the technology also matters. Currently, pumped hydro storage (electricity) and pit, cold water and underground thermal storages are among the technologies in the commercialisation phase. Costs vary significantly. Some technologies are characterised by low upfront capital costs (eg supercapacitors, flywheels at the transmission or distribution level), however the cost per unit of energy capacity can be very high.

Other large-scale energy storage, such as pumped hydro and compressed air storage may have relatively high capital costs but the cost per unit of energy is lower, from US$2 to US$150/kWh. **Figure 2** illustrates the initial investment costs per unit of power for different technologies.

Storage technologies vary in the ancillary services that they can provide. For instance, pumped hydro is suitable for frequency and voltage regulation, while supercapacitors are for voltage regulation, and superconducting magnetic for frequency regulation. A study performed by the US National Renewable Energy Laboratory, which evaluates the value of storage (by adding storage devices of various sizes to a utility system in the western US), suggests a relative low value for arbitraging energy prices, but greater value for provision of ancillary services – indicating the importance of the correct pricing of such services for the viability of storage.

In terms of avoided costs, these can be estimated by the difference between the discounted value of the energy storage and conventional reinforcement investment. The environmental impact is more difficult to quantify. This is not restricted to pollution and gas emissions but also includes land and water use. Pumped hydro storage has the largest use of land and water, with around 1,000 m²/MW (related to a run-of-river plant). A 1,300 MW plant would require 1.1 litres/kWh, or 3bn litres per year.

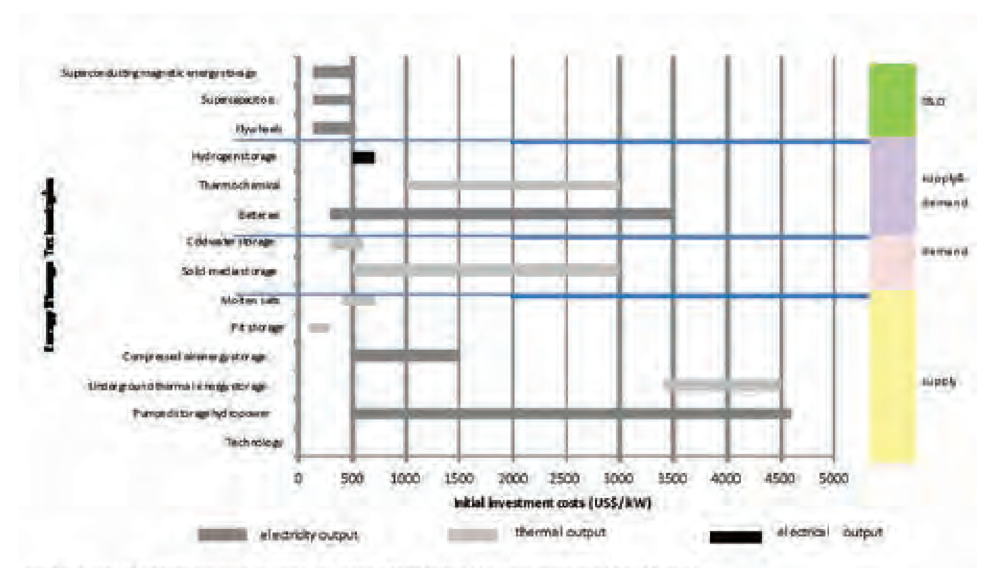

Figure 2. Energy storage initial investment cost per type of technology

Source: IEA, authors' elaboration

Challenges

The GB energy regulator Ofgem has highlighted the need for non-traditional business models to support energy storage. The existence of non-conventional actors such as aggregators and storage operators in the distribution network and their role in the delivery of more flexible networks is becoming more relevant.

Energy storage can have a key role in creating flexible networks that will help to balance supply and demand in the future. This is the case as larger amounts of intermittent renewable energies are injected into the system. In order to maximise its use and benefits, energy storage needs to be integrated at different levels across the generation, transmission, distribution and customer levels.

In terms of barriers, we observe that there are technical and regulatory issues that need to be solved in order to guarantee a smooth deployment of energy storage. Even though energy storage is well established at the transmission level, its extension to the distribution level and the associated commercial arrangements are challenging the conventional way of its integration to the electricity grid. There are few technologies at the commercialisation stage. This indicates the need for continuing R&D to facilitate a wider application of storage technology.

Findings from the SNS project suggest that the energy storage supply chain is still immature, which increases procurement risks to energy storage developers. There is a need for specialist energy storage operators and developers. The lack of incentives or suitable regulation that promotes their expansion is one of the reasons for slowing deployment.

For instance, in GB storage is treated as generation, and then DNOs are subject to unbundling rules which excludes them from owning and operating directly energy storage facilities. DNOs cannot trade in the wholesale market and are restricted in how much they can invest in energy storage. In addition, the charges on energy storage developers/operators may affect them negatively. Energy that is being imported from the grid (at the charging stage) incurs one set of grid charges, while energy exported to the grid (at the discharge stage) is also subject to grid charges. Such double charging does not reflect the value of storage to the grid.

Appropriate energy regulation can also help the expansion of energy storage by promoting market-based initiatives. California is a good example of this, by innovating in the procurement of energy storage capacity with pre-defined business models as suggested by the Public Utilities Commission. Specific energy storage targets have been set for each electric utility and the type of domain (transmission, distribution, customer level). This may decrease the risk that electric utilities may face when starting this kind of initiatives.

According to UK Power Networks, in its search of new business models to support the SNS project, more standardisation in energy supply contracts that involve storage is needed. From our discussion, it is clear that commercial arrangements that involve energy storage are still at an early stage in their development.

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