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Market and regulatory barriers to electrical energy storage innovation

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ABSTRACT

Energy storage has been identified as a priority technology for innovation. However, the rapidly developing family of storage technologies will find it difficult, under the current regulatory regimes, to compete with conventional generators for the provision of electricity system services, and this is likely to impede innovation. This paper analyses and categorizes 16 investment barriers hindering the near-term deployment of energy storage technologies in electricity markets, which are related to four regulatory and public attitudes barriers.

The most important regulatory barrier is the current classification of storage as a generation asset, despite it being unable to provide a positive net flow of electricity, which is used to justify double network usage charges. The merit order design of balancing and ancillary markets hampers the ability of storage technologies to recoup their relatively high capital cost, while capacity markets penalize their limited discharge duration. Network companies are in the best position to realize the system value of storage, but their ownership may only be acceptable if system operation is made independent of network operation.

Current initiatives to address these issues include flexible connection agreements and the development of enhanced frequency response and aggregate fast reserve services. However, to remove the identified barriers, a market structure that valued the flexibility offered by storage, viewing it as complementing rather than competing with network and generation assets, would be required.

1. Introduction

The term ‘electrical energy storage’ encompasses a substantial number of diverse technologies whose aim is to store energy, with the aim of later releasing it in the form of electricity. Most energy storage capacity worldwide is currently comprised of pumped hydropower plants that, due to their economies of scale and large-scale generation capabilities, have traditionally provided a number of system balancing services.

Historically, energy storage in the electricity system has primarily focused on precursors to electricity (e.g. coal; natural gas), with flexible generation capacity being used to meet demand peaks. As weather-dependent renewables and inflexible nuclear power plants take a greater share of the electricity generation markets in the future, frequent excess supply peaks at times of low demand could occur. Electrical energy storage technologies can store this excess energy and use it to meet demand peaks, providing stability and increasing the robustness of low-carbon electricity systems [1]. Storage is unique because it decouples the generation of electricity from its consumption and, in so doing, can help to better manage the grid, optimize the use of current resources, and integrate large-scale renewables.

This potential role for energy storage has led to it being identified as a key technology for the future [2]. For example, the UK Government has identified energy storage as one of ‘Eight Great Technologies’ for the UK [3] and has committed to a program of research and innovation [4]. Yet successful innovation that reduces technology costs requires the deployment of technologies to underpin learning-by-doing [5]. If this innovation drive is to be successful, energy storage will have to be able to compete with other generation in electricity markets.

Energy storage competes with other generation to sell electricity in markets [6]. A combination of high capital costs and regulatory barriers mean that energy storage is uncompetitive in most markets at present. In several countries, governments are considering options to increase energy storage deployment through regulatory changes, e.g. [7,8].

This paper identifies and categorizes the barriers to energy storage in existing electricity markets and considers how these could be addressed to encourage an appropriate level of technological innovation. We study the regulatory definition of energy storage, network barriers, issues related to the ownership and operation of storage by network

Abbreviations: TSO, Transmission System Operator; TNUoS, Transmission Network Use of System (charges); ISO, Independent System Operator; DNO, Distribution Network Operator; DSO, Distribution System Operator; DUoS, Distribution Use of System (charges)

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Table 1
Services that energy storage could provide to the UK electricity system in the current market structure. RoCoF is the Rate of Change of Frequency.

Service	Response duration	Timescale	Role of storage
RoCoF control	< 0.5 s	< 15 min	Charging or discharging in response to frequency deviations
Frequency containment	< 10 s	10–30 s	(Dis)charging in response to loss of generation or load that affects the system frequency
Frequency replacement	< 2 min	< 30 min	(Dis)charging following the loss of generation or load, to stabilize frequency over a longer period
Voltage support	< 1 s	1–60 s	(Dis)charging reactive power to stabilize voltage in the transmission and/or distribution system
Operating reserve	240 min	2–24 h	Discharging at times of high demand in preference to flexible generation
Black start	N/A	N/A	Contributing to the recovery from a partial or total failure of the electricity system which caused an extensive loss of supplies

operators, as well as balancing, ancillary, and capacity market design issues.

1.1. Electricity markets

Until the 1990s, most electricity companies were state-owned and prices were heavily regulated. Since liberalization in most OECD countries, most high-volume consumers have bought electricity through bilateral contracts [9], while other generation has been controlled though a series of markets. The complex price behavior in these markets has reflected the historically-high cost of both storage and spare generation capacity, high demand fluctuations, and a political need for the system to supply all demands at all times with high reliability.

An important large-scale market for electrical energy storage technologies in the long term are the balancing service markets, where investments would be monetized through reserve replacement. Yet energy storage could also offer services in other ancillary markets for fast reserve and grid stability services [10], where they might be more competitive in the near term. These markets are listed for the UK in Table 1. Providing multiple and simultaneous services to several markets could greatly increase revenues and underpin business cases [11], but is difficult to achieve due to operational practicalities. It is also possible that storage may play an important role in the energy wholesale market too, in the longer term, and aggregators are expected to help integrate smaller-scale technologies.

More widely, energy storage technologies could contribute across the electricity system, including to generation (balancing; reserve power), transmission (frequency control; investment deferral), distribution (voltage control; capacity support), and end users (peak-shaving; cost reduction and management) [12].

Changes to electricity markets to encourage energy storage would have two broad aims: (i) to encourage innovation to reduce prices, in the short term; and, (ii) to aim for the optimum deployment that reflects the increasing value of energy storage to the system, in the long term. The likely value of storage in the wider energy system in the future is not well understood. Moreover, the potential role and competitiveness of energy storage in new markets is also unclear, partly because the temporal resolution of existing market models is inadequate to understand the multiple benefits that storage might offer to underpin the business cases for new deployments [13].

1.2. Energy storage technologies

At present, pumped-hydro storage represents 99% of total storage power capacity worldwide, but has only a minor role in most systems. For example, the UK has 80 GW generation capacity but only 3 GW storage capacity [14]. A range of alternative energy storage family of technologies have been developed that have a wide range of physical characteristics [15]. They are at very different levels of maturity, with only a few approaching commercialization. The wide diversity of energy storage technologies creates a challenge for regulators to design market structures and price signals that encourage appropriate levels of innovation across technologies and capture the diversity of the benefits that they can provide to the wider system.

Energy storage technologies can be characterized by power rating and discharge duration, as shown in Fig. 1. Technologies with long

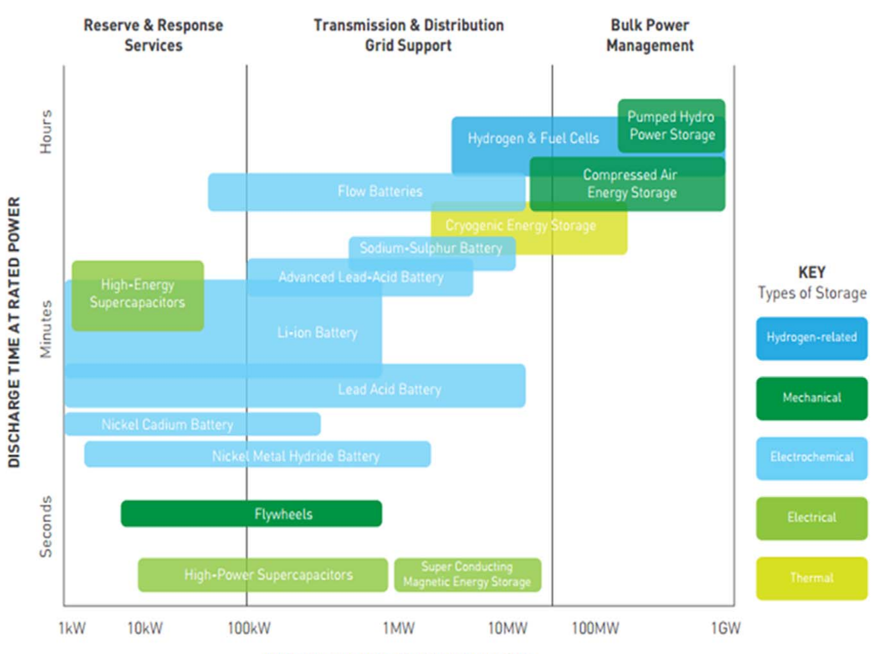

Fig. 1. Key electricity storage technology options to support the system by discharge time (seconds to hours) and system power rating (kW to GW) [16].