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Stationary battery technologies in the U.S.: Development Trends and prospects

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ABSTRACT

In the last years, stationary battery systems started to attract the attention of stakeholders thanks to their unique ability to decouple power generation and load over time, providing the ancillary services necessary for the stability and the reliability of the electrical system. This is especially true in the presence of high levels of penetration of renewable energy technologies, like wind and solar photovoltaic (PV), because of increased fluctuations in the electricity produced by these renewable sources. Despite the growing interest in energy storage technologies, the academic literature has not completely assessed the development trends of this sector. In order to fill this gap, this study strives to address the trends in the spread of stationary battery systems within the U.S. territory. First, the U.S. policy legislation within the different U.S. states is reviewed, with particular emphasis on support policies put in place in the different states. Second, based on the analysis of the Department of Energy (DOE) Energy Storage Database, the main trends in battery systems installations within the U.S. are identified and presented in this paper, with reference both to the viable use cases and to the main electrochemical technologies currently spread in the storage market. The analysis carried out in this work could help stakeholders to assess the impact of energy storage policies in the different U.S. states, identifying the future trends and the most promising markets within the U.S. territory.

1. Introduction

The deployment of Renewable Energy Sources (RESs) in the electricity sector, like wind and solar photovoltaic (PV), spurred by advantageous policy measures carried out in several countries [1–8], has led to concerns regarding the stability and the reliability of the electrical system. In order to overcome the stability issues, energy storage systems (ESSs) can advantageously be used, thanks to their unique ability to decouple power generation and load over time, providing the ancillary services necessary for the stability and the reliability of the electrical system [9,10]. Among the energy storage sector, electrochemical technologies are gaining more and more interest thanks to their versatility features. Indeed, batteries have favorable technological characteristics such as fast response time, modularity and scalability. Furthermore, most of the electrochemical technologies have a high potential for cost reduction and, as such, are recently receiving increasing attention within industry, academia and politics. From a technological viewpoint, most of electrochemical storages are mature technologies, but several problems, such as safety issues, performance, regulatory barriers and utility acceptance remain to be overcome.

In recent years, significant progress is being made in the electrochemical sector, and a large number of battery projects are being deployed around the world. The countries leading on electrochemical storages are shown in Fig. 1, in terms of cumulated MW installed and number of electrochemical storage installations.

In term of electrochemical storages only in operational status, Fig. 2 shows the cumulated MW installed and the number of electrochemical storage installations in 2015.

The U.S. is on the first place, with a total estimated power of

Abbreviations: APS, Arizona Public Service; ARRA, American Recovery and Reinvestment Act; CPUC, California Public Utilities Commission; DEEP, Department of Energy and Environmental Protection; DOE, Department of Energy; ERCOT, Electric Reliability Council of Texas; ESSs, energy storage systems; FERC, Federal Energy Regulatory Commission; GMP, Green Mountain Power; IRR, internal rate of return; ISO, Independent System Operators; KIUC, Kaua'i Island Utility Cooperative; Li-ion, lithium-ion; LIPA, Long Island Power Authority; NaS, sodium-sulphur; NEM, net energy metering; NJBPU, New Jersey Board of Public Utilities; NPV, net present value; NYSERDA, New York State Energy Research and Development Authority; PGE, Portland General Electric; PG & E, Pacific Gas and Electric Company; PV, photovoltaic; QER, Quadrennial Energy Review; RESs, renewable energy sources; RFP, request for proposal; RTO, Regional Transmission Operator; RUCO, Residential Utility Consumer Office; SCE, Southern California Edison; SDG & E, Company and San Diego Gas & Electric; SGDP, Smart Grid Demonstration Program; SGIP, self-generation incentive program; VPS, Vermont Public Service

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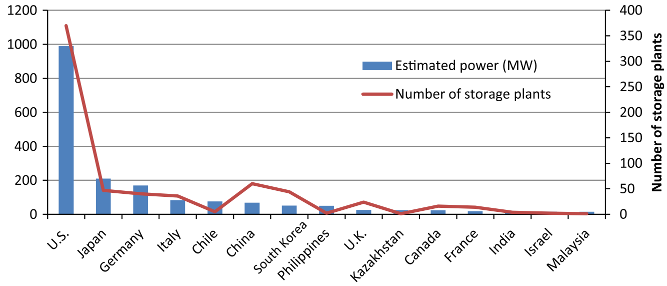

Fig. 1. Estimate of battery storage (MW) in the power sector by country (operational, announced, contracted, under construction, decommissioned, off-line, under repair), in 2015.

354 MW (192 storage installations). Follow Japan, with 97 MW (35 storage installations) and China, with 48 MW (53 storage plants). South Korea is at the fourth place, with 38 MW, followed by Chile (32 MW), Germany (29 MW), the U.K (22 MW), the Netherlands (14 MW) and France (11 MW). The other countries are below 10 MW of estimated power. In terms of number of storage plants, China has a high number of electrochemical installations (compared to its estimated power) while Chile only has two electrochemical installations of very high size (20 MW and 12 MW, respectively). The US Department of Energy (DOE) Storage database was used for gathering the data [11]. The data shown in Fig. 1 and Fig. 2 underestimate battery storages, since decentralized storage plants are not included, due to the small size and private nature of these installations.

Despite the growing interest in energy storage technologies around the world, the academic literature has not yet fully assessed the development trends of this sector. In order to fill this gap, this study strives to address the trends in the spread of stationary battery systems within the U.S. territory.

As a first step, a literature review on the feasibility of ESSs in the U.S. is reported. Second, the U.S. policy legislation within the different U.S. states is reviewed, with particular emphasis on support policies put in place in the different states. Finally, based on the analysis of the DOE database, the main trends in battery systems installations within the U.S. are identified and presented in this paper, with reference both to the viable use cases and to the main electrochemical technologies currently spread in the storage market. The analysis carried out in this work could help stakeholders to assess the impact of energy storage policies in the different U.S. states, identifying the future trends and the most promising markets within the U.S. territory.

2. Literature review

The economic feasibility of storage systems in the U.S. has been evaluated by several authors, with different results. Walawalkar et al. [12] evaluated the economic feasibility of sodium-sulphur (NaS)

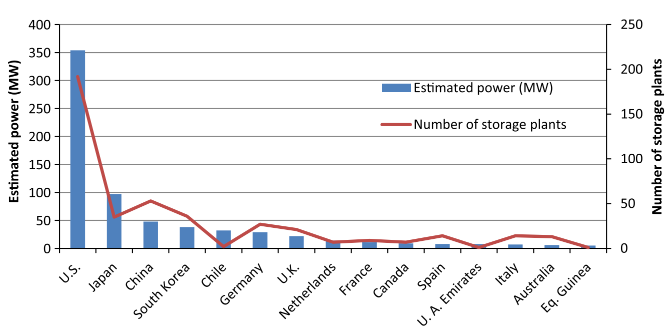

Fig. 2. Estimate of battery storage (MW) in the power sector by country (in operational status), in 2015.

batteries for arbitrage and flywheels for frequency control in the New York City region. They concluded that both NaS batteries and flywheels have a high probability of positive net present value (NPV), and that the storage efficiency is the most important factor for developing storage systems in a competitive electricity market. Sioshansi et al. [13] analyzed the arbitrage value of a price-taking storage device in PJM (a regional transmission organization in the U.S.) during a the six-year period from 2002 to 2007, to understand the impact of fuel prices, transmission constraints, efficiency, storage capacity, and fuel mix. Byrne and Silva-Monroy [14] estimated the maximum potential revenue from participating in arbitrage and regulation services, using a linear programming optimization approach. They found that the participation in the regulation market produces four times the revenue compared to arbitrage in the CAISO market (a Californian utility), using 2010 and 2011 data. Aucker et al. [15] analyzed more than 200 publications on the economics of storage systems, concluding that regulation is a primary factor to increase the widespread of electricity storages and that grid fees are a main factor against storage development. In [16] Bhatnagar et al. identified the key barriers against a further development of ESSs, through interviews with stakeholders in four regions of the U.S.. They concluded that ESSs could have a key role in the future energy systems, but market and regulatory issues will need to be addressed. Ellison et al. [17] examined how the operation of Nevada electrical system can benefit from electricity storages, evaluating whether those benefits justify the cost of electricity storages. They found that: i) all storage scenarios examined allow the grid to be operated at lower costs; ii) the added value is maximum when storage systems are used for regulation and spinning reserve. Chen et al. [18] introduced the framework of frequency regulation compensation in the U.S. (see Section 3), giving suggestions for further improvement of frequency regulation market, based on the analysis of regulatory practice and operational experience of frequency regulation service in China. Anuta et al. [19] reviewed countries with high renewable targets and with significant ESSs deployments, concluding that the major problems limiting stakeholders from determining and realizing multiple ESSs benefits are: i) low electricity market liquidity, ii) changing market conditions and iii) lack of common standards and procedures for evaluating, connecting, operating and maintaining ESSs. Bradbury et al. [20] examined seven real-time markets in the U.S. and 14 different ESS technologies used in arbitrage applications. They found that the profit-maximizing size (i.e. hours of energy storage) of an ESS is primarily determined by its technological characteristics (round-trip charge/discharge efficiency and self-discharge), rather than the magnitude of market price volatility, which instead increases the internal rate of return (IRR).

DiOrio et al. [21] reviewed customer sited behind the-meter storages coupled with PV, estimating the financial benefit of customer-installed systems in California and Tennessee. They considered different dispatching strategies, including manual scheduling and automated peak-shaving, to increase the system value and mitigate demand charges. They found that the installation of PV systems with lithium-ion (li-ion) batteries in Los Angeles and the installation of li-ion batteries without PV in Knoxville, yields positive NPV considering a battery costs of $300/kWh and high demand charge utility rate structures, under the assumption of perfect day-ahead forecasting. Finally, Byrne et al. [22] developed a linear programming method for estimating the maximum potential revenue of an ESS from participating in arbitrage and regulation market, using the PJM's pay-for-performance remuneration model.

3. U.S. policy legislation

The U.S. is a market leader in stationary battery storage, accounting for around half of the overall world capacity. The U.S. storage market experienced a quick growth in the last years; indeed, the U.S. Energy Storage Monitor predicted that 192 MW of energy storage projects will