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Is inexpensive natural gas hindering the grid energy storage industry?

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HIGHLIGHTS

- We use engineering–economic models to determine breakeven capital cost of storage.
- Two applications are examined: frequency regulation and energy arbitrage.
- For both services, potential revenue has decreased significantly since 2008.
- We show a high correlation of revenue with natural gas price.
- We demonstrate a causal relationship using the PHORUM grid modeling software.

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ABSTRACT

Grid energy storage is a maturing technology and forecasts of the industry's growth have been promising. However, recent years have realized little growth in actual deployments of grid-level storage and several high-profile storage companies and projects have failed. We hypothesize that falling natural gas prices have significantly reduced the potential profit from many U.S. energy storage projects since 2009 and quantify that effect. We use engineering–economic models to calculate the monthly revenue to energy storage devices providing frequency regulation and energy arbitrage in several electricity markets and compare that revenue to prevailing natural gas prices. We find that flywheel devices providing frequency regulation were profitable in months when natural gas prices were above $7/mcf, but face difficulties at current prices (around $4/mcf). For energy arbitrage alone, we find that the breakeven capital cost for large-scale storage was around $300/kWh in several key locations in 2004–2008, but is around $100/kWh in the same locations today. Though cost and performance improvements have been continually decreasing the effective cost of energy services from storage, fundamental market signals indicating the need for energy storage are at or near 10-year lows for both energy arbitrage and frequency regulation.

1. Introduction

Historically, electricity systems have had limited energy storage capacity. Energy storage today makes up less than 3% of total installed capacity in the U.S., almost all of which is in the form of pumped hydro storage (EPRI, 2010). Although energy storage can provide many services beneficial to the grid, high capital costs, technical issues, and regulatory difficulties have historically limited deployment. However, trends over the last twenty years have increased interest in energy storage: the difference between peak and off-peak load is increasing in most regions of the US, variable and intermittent renewables are being added at a rapid pace, and new energy storage technologies are being created and improved. Even though some grid storage technologies have been operating for decades, policy makers have only recently started discussing energy storage, resulting in storage mandates, subsidies, and storage-focused rulemaking from regulatory bodies. For example, the Storage Technology for Renewable and Green Energy Act (STORAGE) in 2013 proposed changes in the Internal Revenue Code of 1986, so that an energy investment credit would be provided for energy storage connected to the grid (US Senate Committee on Energy and Natural Resources, 113th Congress, 1st Session). In 2010, the California Senate passed AB2514, directing the California Public Utilities Commission (CPUC) to determine appropriate requirements for grid energy storage (AB 2514, 2010). Three years later, the CPUC mandated that the three major investor-owned utilities in California must collectively add 1.3 GW of storage by 2020 (California Public Utilities Commission, 2013).

Since 2008, funding by the federal government for energy

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storage has increased substantially. The American Recovery and Reinvestment Act (ARRA) of 2009 provided $185 million in federal funding for 16 storage projects (US Department of Energy, 2013a, 2013b). Total federal funding for battery and energy storage initiatives totaled $1.3 billion for fiscal years 2009–2012. Along with funding research, the U.S. Department of Energy (DOE) has set cost reduction targets for storage technologies. DOE's Office of Electricity Delivery has a target of $250/kWh for sodium–sulfur, lead–acid, lithium ion (Li-ion), and flow batteries (US DOE, Office of Electricity Delivery & Energy Reliability, 2011). DOE's Advanced Research Projects Agency- Energy (ARPA-E) has funded research into “revolutionary new technology approaches to grid-scale energy storage” with capital costs as low as $100/kWh (US DOE Advanced Research Projects Agency-Energy, 2010).

These research and policy efforts have led to significant improvement into advanced energy storage technologies such as compressed air energy storage, electrochemical flow batteries, and flywheels. More mature storage technologies (Li-ion, nickel cadmium (NiCd), and lead–acid) are now deployed at utility scale. Several large grid energy storage projects have been commissioned since 2000 (Table 1). Based on this early activity and promising estimates of the value of grid energy storage (EPRI-DOE, 2002; Eyer et al., 2004), industry forecasts suggested exponential growth in the deployment of short-duration storage, such as batteries (Fig. 1).

However, the industry has experienced some difficulties. Beacon Power, a prominent flywheel manufacturer, filed for bankruptcy in 2011 following the successful deployment of their New York flywheel frequency regulation plant. The firm was later acquired by Rockland Capital (Postelwait, 2013). The Iowa Stored Energy Park, a 270 MW, $400 million project intended to integrate wind generation, was canceled in 2011 due to unforeseen problems with the project’s economics and geology. Sandia's Energy Storage Systems Program wrote a "lessons learned" report about this cancelled CAES plant (Schulte et al., 2012). They state in the abstract of this report that one of the important lessons from the cancelled project is to carefully consider "...the costs and long-term economics of a CAES facility compared to conventional natural gas-fired generation alternatives". And the general trend of grid-level deployments of energy storage has been flat or declining for years, despite earlier predictions of rapid and robust growth in the market (Fig. 2). The contrast between predictions of robust growth with low adoption of the technology leads to an obvious and important question: why are actual deployments of energy storage lower than expected?

We hypothesize that falling natural gas prices have significantly reduced the potential profit from several types of U.S. energy storage projects since 2009, offsetting the technological improvements in storage technologies made over the same period. While this relationship has been proposed and discussed in the past, in this work we quantify its effect using historical data. Power generation from natural gas is a good substitute for many energy storage applications, including frequency regulation, energy arbitrage, and renewables integration. Furthermore, the price of wholesale natural gas has a large effect on the price at which natural gas generation and services are offered on the market because the levelized cost of electricity for natural gas generators is mostly due to fuel cost. For natural gas generation, 50–70% of the levelized cost of electricity is due to the fuel (US Energy Information Administration, 2014a, 2014b, 2014c). This is not the case for other technologies such as coal power, for which fuel costs are less than 30% of the total cost of electricity. Furthermore, while all generators tend to bid close to their marginal costs, natural gas is an energy source with both higher average prices and higher price volatility than coal. Thus, decreasing natural gas prices (Fig. 3) significantly decrease the cost of services from natural gas generation, which is perhaps the main competitor for grid energy storage in many applications. Stated another way, natural gas prices both have a stronger effect on the levelized cost of electricity and are historically more volatile than other fuels used to

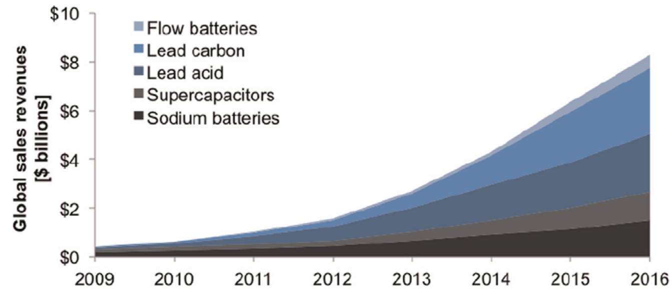

Fig. 1. NanoMarkets’ 2009 forecast of global sales revenues of smart grid energy storage (Data from (NanoMarkets, 2009)).

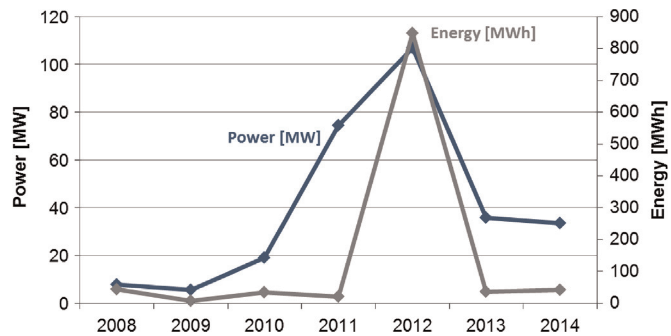

Fig. 2. Total grid-tied energy storage capacity commissioned by year, 2008–2014 (US Department of Energy, 2014). Excludes thermal storage. Installed energy capacity [MWh] was high in 2012 due to the commissioning of the 8-h duration Olivenhain–Hodges pumped hydropower facility.

Table 1
Operational U.S. storage projects larger than 20 MW, commissioned since 2000. Data are from the US Department of Energy Global Energy Storage Database. Thermal storage is excluded due to reporting oddities.

Developer	Technology	Rated power [MW]	Duration at rated power [minutes]	Primary use	Commission date	State
Golden Valley Electric Asssociation	NiCd	27	15	Spinning reserve	Dec 2003	AK
Beacon Power, LLC	Flywheel	20	15	Frequency regulation	Jan 2011	NY
AES	Li-ion	32	15	Frequency regulation	Sept 2011	WV
Duke Energy	Lead acid	36	40	Renewables capacity firming	Oct 2012	TX
San Diego County Water Authority	Pumped Hydro	40	360	Load Shifting	Sept 2012	CA
AES	Li-ion	20	Not reported	Frequency regulation	Sept 2013	OH
Beacon Power, LLC	Flywheel	20	15	Frequency regulation	Jul 2014	PA