Potential for Storage Arbitrage in South Korea's Electricity Markets

Anastasia Shcherbakova*, Andrew Kleit, Seth Blumsack, Joohyun Cho

Department of Energy and Mineral Engineering
Penn State University

Overview

Introducing the use of storage devices into existing electricity networks can potentially help to address the challenge of rising peak power demand and generation costs by making lower-cost power generated during off-peak times available to meet peak-time demand. However, storage remains a weak spot of electricity markets, partly due to the high cost of small storage devices that prevent individuals from entering the market. Empirical studies differ on the economic viability of storage. Some authors have found that potential storage arbitrage profits are not always sufficient to offset the capital cost of the storage device (Ekman & Jensen 2010, Walawalkar et al. 2007), while other simulations demonstrated more promising results (Walawalkar et al. 2007, Sioshansi et al. 2009). In this study we evaluate the economic viability of storage in South Korean electricity markets. Specifically, using hourly day-ahead system marginal electricity prices (SMPs), published by Korea Power Exchange (KPX), and a set of charging and discharging rules, we calculate annual arbitrage profits resulting from operation of a small battery between 2009 and 2011.

Methodology

This analysis relies on the assumption of a price-taking battery operator. In other words, SMPs set by market supply and demand are exogenous to operation of our hypothetical storage device. We introduce into Korea's existing electricity market a hypothetical sodium-sulfur (Na-S) battery, commonly accepted as a viable grid-scale storage device, with a charging capacity of 7.5 MWh, round-trip charging efficiency of 86 percent[1], and a depreciation cost of 5 US cents per KWh[2] (approximately 50 KRW).

Assuming perfect foresight with respect to prices and a one-day forward horizon for storage decisions, we calculate arbitrage profits available to a storage device owner during each year under our analysis. Beginning on January 1st, a battery operator decides when to purchase power from the grid to store in the device and when to sell it back to the system in order to maximize operating profits. Charging happens during hours with the lowest SMPs of the day, while discharging occurs during hours with the highest SMPs of the day. A one-day forward decision-making horizon implies that the battery does not need to be fully emptied at the end of a given day. Rather, the battery owner has an option of retaining this power to be sold to the grid during the following day, given that appropriate profit opportunities exist.

Results and Policy Implications

Results of empirical simulation, displayed in Table 1 below, show that storage arbitrage is generally profitable in Korea's power markets, although profit potential differed widely across the three years

* Corresponding author. 153 Hosler Building, University Park, PA 16802. Email: aus29@psu.edu. Phone: 814-865-9136.

[1] This figure is based on a one-way battery charging and discharging efficiency of 93 percent, commonly cited in engineering literature.

[2] Peterson et al., 2010.

evaluated. The highest profitability occurred in 2010, with 14.1 million KRW generated from energy arbitrage. 2009 yielded the lowest profit potential of 2.7 million KRW, though not the lowest profit per KWh of energy sold. Profitability is affected by two main factors: the size of the spread between peak and off-peak prices, and the number of hours during which a sizable spread occurs. The larger both of these are, the higher arbitrage profits a battery operator will earn. The low profitability of 2009 appears to be due to a low number of sufficiently price-differentiated hours.

The economic viability of small scale storage arbitrage in South Korea is good news for a country that has faced challenges related to historically low fixed retail electricity rates. However, large annual variation in profitability could prove to be a significant barrier for electric storage penetration, since storage owners would be giving up a number of more attractive investment opportunities during low profit years. This possibility may be enough to discourage entry.

Table 1: Annual storage arbitrage profitability results

Year	Total annual profit (KRW)	Total amount of energy sold (KWh)	Profit per unit of energy sold (KRW/KWh)	Profit per day (KRW)
2009	2,652,239	114,167	23.23	7,266
2010	14,127,066	467,046	30.25	38,704
2011	6,372,768	358,599	17.77	17,460

References

Barbour, Edward, I. A. Grant Wilson, Ian G. Bryden, Peter G. McGregor, Paul A. Mulheran and Peter J. Hall, "Towards an objective method to compare energy storage technologies: development and validation of a model to determine the upper boundary of revenue available from electrical price arbitrage," *Energy and Environmental Science* 2012 (5) pp. 5425-5436.

Ekman, Claus Krog, and Soren Hojgaard Jensen, "Prospects for large scale electricity storage in Denmark," *Energy Conversion and Management* 51 (2010) pp. 1140-1147.

Peterson, Scott B., J.F. Whitacre, and Jay Apt, "The economics of using plug-in hybrid electric vehicle battery packs for grid storage," *Journal of Power Sources* 195 (2010) pp. 2377-2384.

Sioshansi, Ramteen, "Welfare impacts of electricity storage and the implications of ownership structure," *The Energy Journal* 31(2), 2010, pp. 173-198.

Sioshansi, Ramteen, Paul Denholm, Thomas Jenkin, and Jurgen Weiss, "Estimating the value of electricity storage in PJM: arbitrage and some welfare effects," *Energy Economics* 31 (2009) pp. 269-277.

Walawalkar, Rahul, Jay Apt, and Rick Mancini, "Economics of electric energy storage for energy arbitrage and regulation in New York," *Energy Policy* 35(2007) pp. 2558-2568.