Batteries as Energy Storage for Energy Shifting

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Abstract: As the costs of building large-scale batteries decrease and some governments provide incentives for integrating batteries into the power grid, electricity generators and users are exploring the economic viability of using batteries for energy storage. The primary value of such storage comes from energy shifting: Storing electricity when the power supply is abundant and cheap, and releasing electricity when the supply is tight and expensive. This paper is the first to provide an analytical framework for assessing battery investment and operation decisions for energy shifting. The main challenge for such an analysis is that battery capacity deteriorates with usage and its deterioration rate depends on how deeply the battery is discharged (i.e., the depth of discharge, or DoD). We develop a model to characterize the empirical relationships among battery capacity, depth of discharge, and useful life. The model allows us to find the discharge decisions that maximize total discounted revenue. The optimal policy has one of three simple structures: Discharge the battery by the maximum allowed depth of discharge (constant DoD policy), or by a constant amount of energy (constant energy policy), or by an amount that decreases exponentially in time (exponential energy policy). We provide a case study that provides guidance into how to build the revenue function for energy shifting, and that illustrates our results.