Integrating Data Center Battery Storage with the Grid: Participation in Frequency Regulation Markets

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Batteries in Data Centers

Battery storages are extensively used in data centers as failover to onsite local generation

- Sized to sized to the capacity of the data center: a 10 MW data center will have a storage system with the power rating of10 MW with several minutes of energy capacity.
- Despite their potential to grid services, these battery storage systems are not integrated with the power system.

Challenges and Opportunities

Whether a battery taking part in grid services is predominantly determined by the economic benefits of these services.

- Batteries must still serve as reliable backup
- Batteries degrade faster
- More complex operations
- Many potential markets to participate in: energy arbitrage, regulation markets, demand response,…

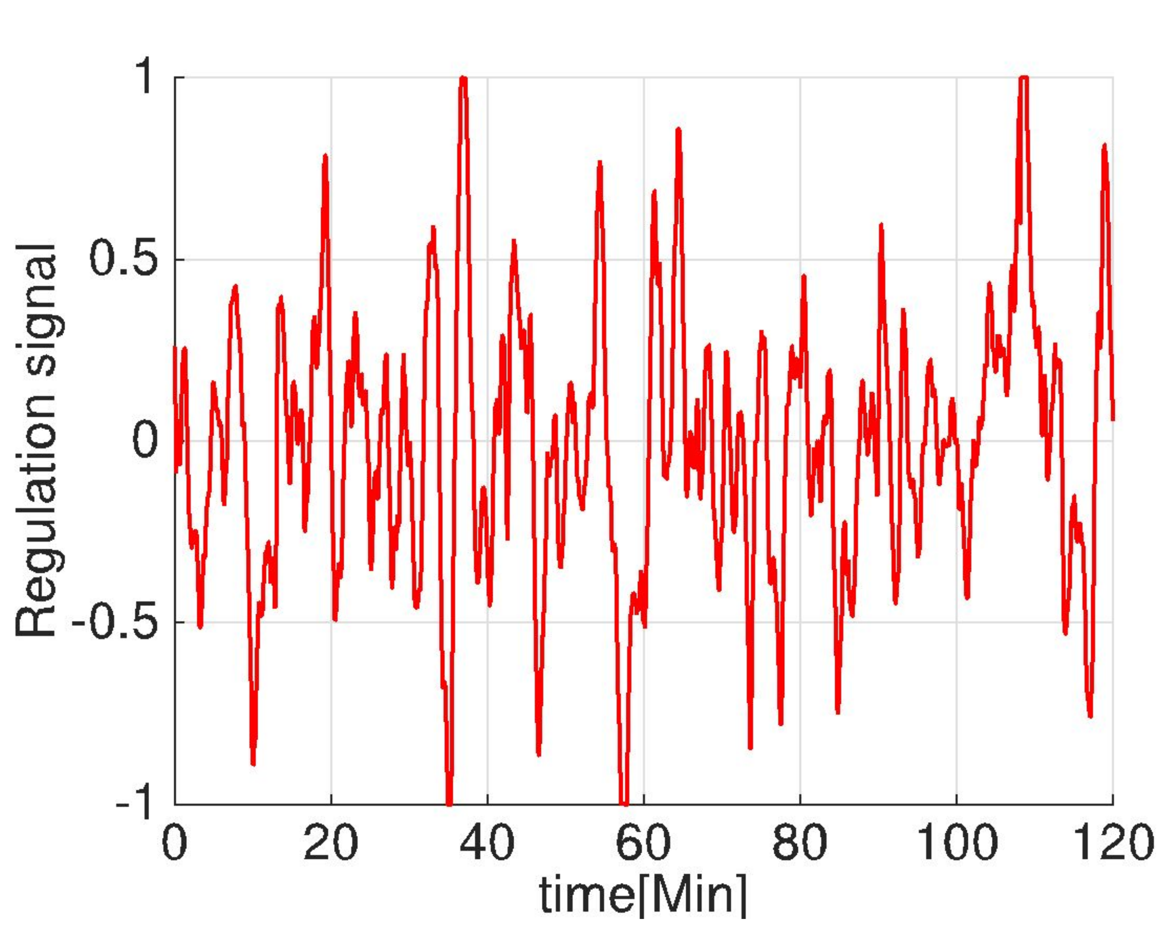
We consider the frequency regulation market

Frequency Regulation Market

Short-term balancing of the system load and generation

- Operator sends a signal every 2 or 4 seconds that captures the net demand
- Signal is normalized between [-1,1]
- A participant injects power based on the scaled value of this signal

PJM Regulation Signal

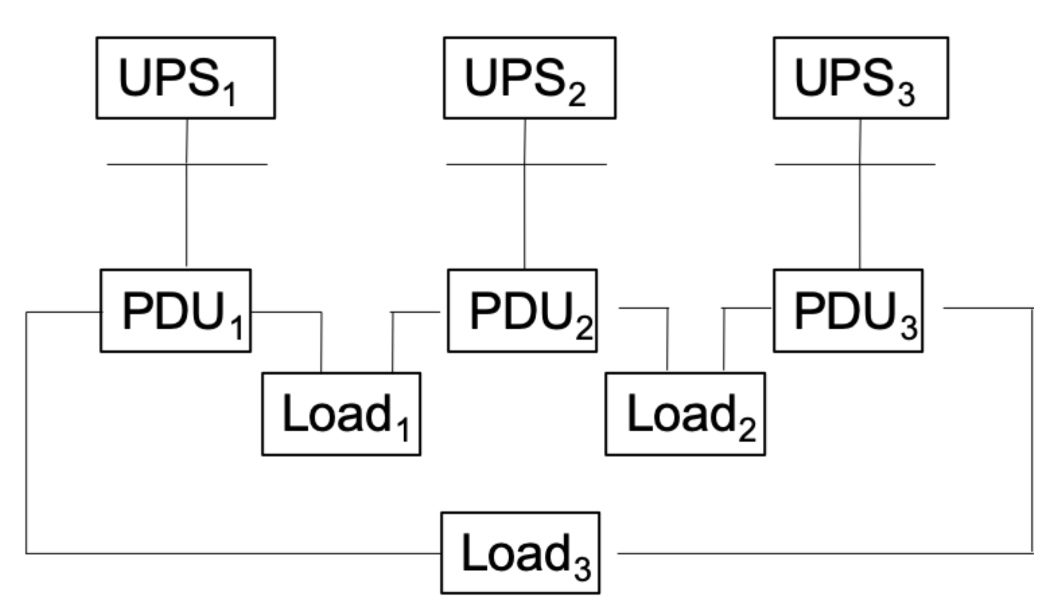


Data Center Configuration

Battery configurations

- Batteries are configured to provide redundancy in different architectures
- We consider N+1 distributed redundant configurations
- Tolerate failure of any single component

Example of N+1 Redundant Configuration



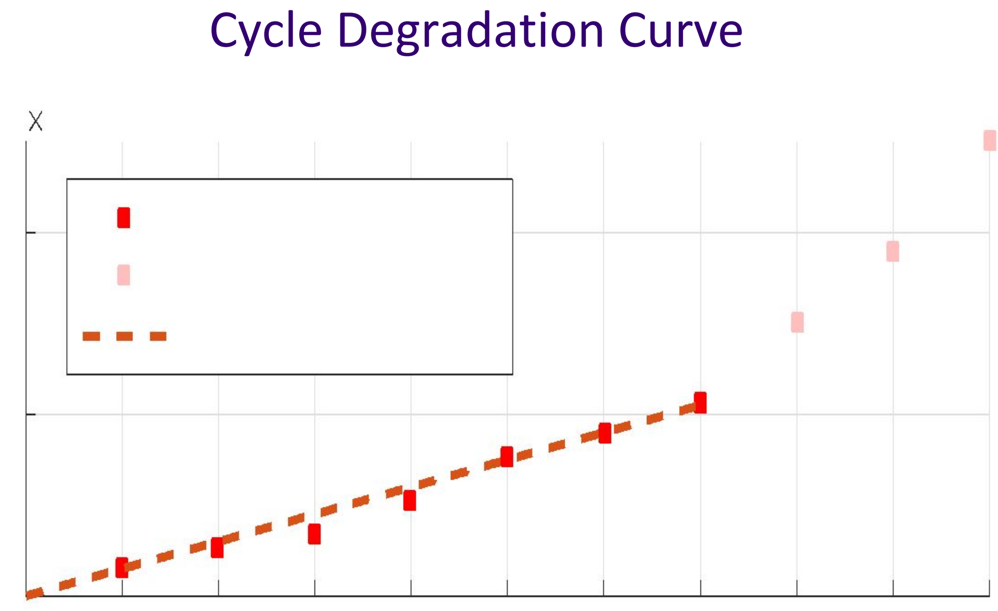
Battery Degradation

Battery degradation depends on many factors

- Calendar aging
- Temperature
- Cycle-based (charge and discharge)
- SoC levels

In operations, we consider cycle-based and average SoC degradations

Cycle Degradation Curve



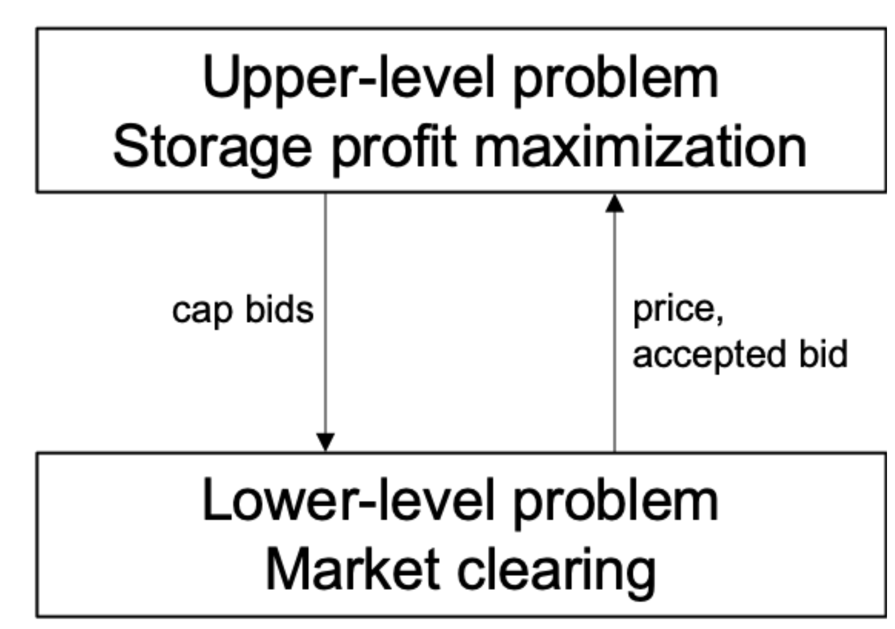
Degradation curves

- Fit from experimental data
- Real-time learning
- Convert to a monetary value through replacement costs

Optimization Model

Finding the optimal regulation capacity and battery operations to maximize the payoff of a data center subject to the N + 1 redundancy constraint

- Bi-level optimization framework:

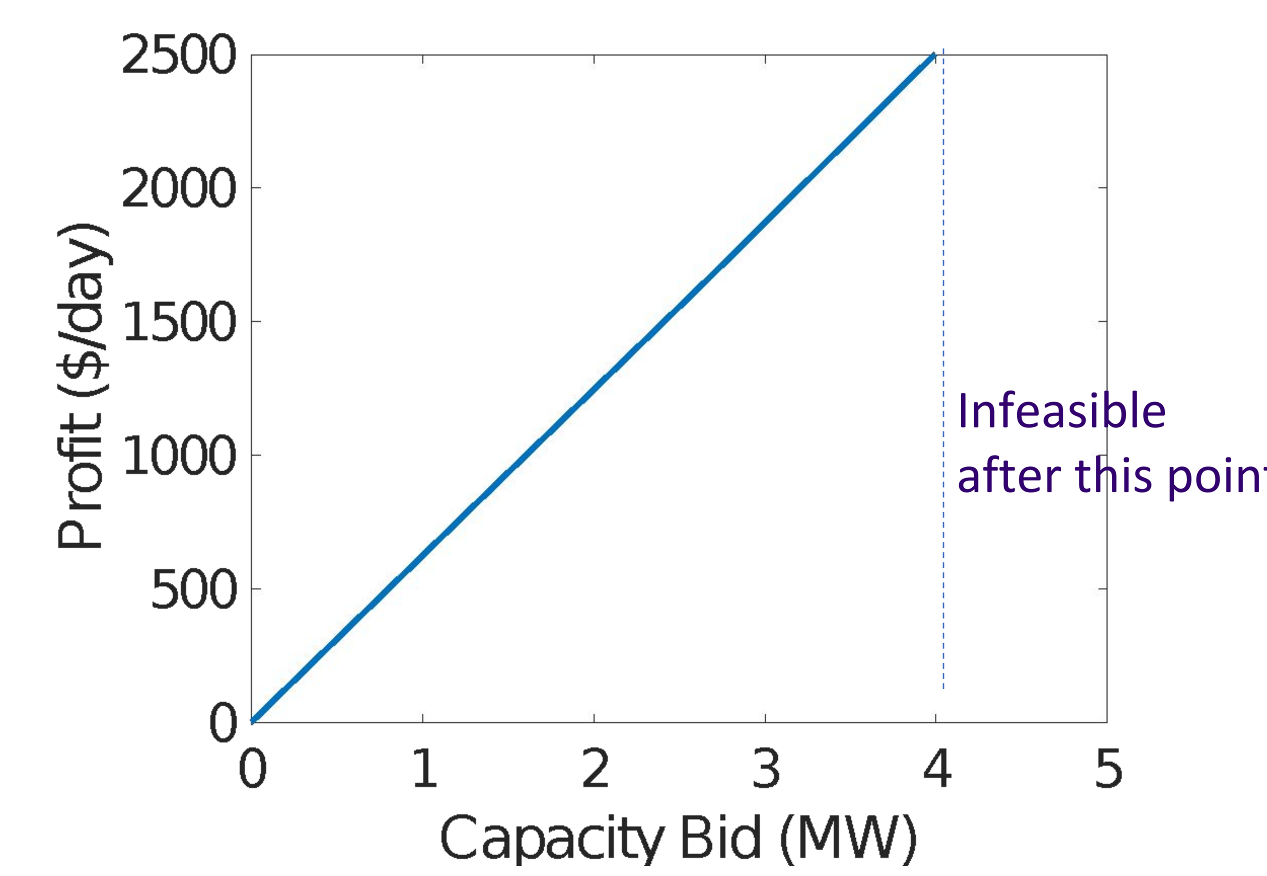


Optimization Problem:

- Find the bid capacity that maximizes the profit
- Subject to data center reliability constraints and regulation service constraints
- A participant need to meet a certain level of response to remain in the market

$$\begin{aligned}\max_{C,p}\ & C\cdot LL(C,\lambda) - UL(cost)\\ \text{s.t. } & \text{battery constraints}\\ & N+1 \text{ constraints}\\ & \Pr(\text{regulation is met}) \geq 0.9.\end{aligned}$$

Simulation (10 MW data center)



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