[20] [Battery to peak shave and frequency regulation](https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8027056)

Battery joint optimization for peak shaving and (fast) frequency regulation.

In presence battery degradation, operational constraints, uncertainties from customer and regulation signals

Superlinear gain: gain revenue is larger than individual optimization

Two commercial examples: Microsoft data center and UW EE,CSE buildings

1. CONSUMER BILL

* Two parts: Energy charge and peak demand charge

Combined is total cost\

1. Peak shaving

B(t) is battery , b(t) >0 discharging.

Peak shave then

1. Frequency Regulation Service

Gets revenue with mismatch penalty, and operation cost

1. Consider degradation

Limit operation within certain DoD range and assign marginal cost for charge/discharge

Joint optimization

A math equations and formulas

Description automatically generated with medium confidence

A list of energy symbols

Description automatically generated

Assumes complete knowledge of future: so best scenarios (Offline)

A table with numbers and text

Description automatically generated

Online Control: 2-step optimization: 1) Day-ahead decision on peak shaving threshold and frequency regulation capacity bidding (MLR)

2) real-time control of charge discharge

Simulation results + Sensitivity analysis (How different demand charge, degration cost, regulation payments, influence super linear gains??)

Conclusion: Use battery storage in large commercial banks to reduce bills from two sources: shaving peak demand and frequency regulation . Surprising! Super linear gain. Degradation is linear form, may need to incorporate more general degradation framework