Optimisation of battery charging and discharging

Here, we formulate a model that optimises an agent’s market strategy for a given portfolio of storage devices and known market prices.

# Definition of sets, parameters, and decision variables

## Sets

## Parameters – Battery Energy Storage

## Parameters - Generation

## Market

## Decision variables

# Problem Formulation

## Objective: Profit maximisation over optimisation horizon

There are three potential aspects of the agent’s objective value. , the net revenue from participating in the electricity market. , the penalty from deviating from the ideal end of horizon storage stage . Finally, we have, the cost of the degradation of the storage devices.

### (1a) Definition of revenue ()

The net revenue from selling generation at each time step is defined by . This equation, includes the net power sold to the market is a function that converts the energy discharged, to the power received by the grid from storage unit at timestep . Thus, by subtracting the power used to charge each storage device, the net energy sold to the grid is given by . By multiplying the price of energy, we obtain the net revenue per hour. Finally, by summing this rate of profit for each storage unit, and each timestep and multiplying this by the length of each timestep (in hours) we have the net revenue over the optimisation horizon.

### (1b) End of Horizon penalty ()

There is an incentive to use up all of the energy in each storage device by the end of the optimisation horizon. To disincentivise this behaviour and more accurately represent the optimal charging and discharging at the end of the optimisation horizon, we include a penalty function for deviating above, and deviating below, ideal storage level, at the end of the optimisation horizon. Each cost function is convex. We then sum across each storage unit, to obtain the net penalty.

### (1c) Cost of degradation ()

Operating each storage unit, leads to long term degradation of each storage unit. We represent 3 types of long term degradation: Discharging , charging and storage . To obtain the overall cost, we sum across the optimisation horizon, and each storage unit, and multiplying this rate of degradation by the length of each timestep .

### (1d) Cost of generation ()

In cases where we are responsible for satisfying demand with an insufficient amount coming from the grid, we will have to use our own source of electricity generation. To obtain the overall cost, we sum across all generation units, and timesteps, giving:

## Constraints

### (2a) Definition of the state of the energy storage state

The energy stored depends on three things in our formulation: The energy retained from the previous time-step, the energy used to charge the device, and the energy discharged from the device. Mathematically this gives:

### (2b) End-of-horizon conditions

Here we define some end of horizon constraints on the storage devices, ensuring the end-of-horizon storage is within a particular range, and defining the shortage or excess if the EOH storage is not at the ideal level, .

#### (2b.i) Defines end of horizon storage excess or shortage from ideal

#### (2b.ii) Limit on end-of-horizon storage excess from ideal

#### (2b.iii) Limit on end-of-horizon storage shortage from ideal

### (2c) Limits on charging and discharging of storage devices

Here we limit the power charging and output capabilities of each storage unit

#### (2c.i) Charging Limit

#### (2c.ii) Discharging Limit

### (3) Ramping constraints of each storage unit

#### (3a) Ramping up limits

#### (3a) Ramping down limits

### (4) Enforced normal operation range

#### (4a) Upper limits

These constraints limit storage within a range to preserve its operation life

#### (4b) Lower Limits

### (5) Electricity generation

For now, we constrain electricity generation fairly simply, with an upper bound, which may change over time.

### (6) Real-time load balancing

For cases where it is our job to ensure there is a load balance, we have the load balancing constraint that balances generation, battery storage and discharge, and demand.

### (7) Non-negativity constraints

Finally, we constrain the energy stored, power consumed/discharged, and energy shortage/excess decision variables to be non-negative.