REVENUE OPTIMIZATION FOR BATTERY STORAGE

Modelling energy production is a core task for those developing, financing, and operating renewable energy projects. However, with battery storage, since no energy is being produced, the main consideration to model is when should the battery charge and discharge? To answer this we need to define what we mean by "should" and come up with a way to represent the physical attributes of battery storage and the commercial/market rules for how they are allowed to operate. This type of problem lends itself to a method called optimization. We define an objective (the "should"), apply constraints (which captures the physical and commercial/market attributes), and determine the decisions that lead to the best outcome. This case study describes the intuition behind optimization and how applying different constraints impacts results.

problem: optimization problem
Should: Timing for charging and discharging i guess

Objective: When to charge and discharge
Constraints: - Physical and Commercial market attributes
Decision Variables: Levers

BATTERY STORAGE BASICS

A battery energy storage system (BESS) is an electrochemical device that charges (or collects energy) from the grid or a power plant and then discharges that energy later to provide electricity or other grid services when needed. Key technical characteristics of BESS are:

- Power Capacity (kW or MW) is the total possible instantaneous charge/discharge capability of the BESS
- Energy Capacity (kWh or MWh) is the maximum amount of stored energy in the BESS
- Storage Duration (h) is the number of hours BESS will take to discharge at its power capacity before depleting its energy capacity or vice versa
- State of Charge, SOC (%) represents the battery's present level of charge and ranges from completely discharged (0%) to fully charged (100%)
- Charging efficiency (%) is the energy charged to the battery divided by the energy consumed from the grid
- Discharging efficiency (%) is the energy supplied to the grid divided by the energy discharged by the battery

WHAT IS OPTIMIZATION?

Optimization is the process of maximizing or minimizing an objective function by finding the best available decisions across a set of inputs. When applied to energy storage modeling, the objective function is to maximize revenue given a set of constraints.

Those constraints are driven by both physical battery and electrical properties and market-based rules. To understand how to maximize revenue, we also need to have some price expectation. For the rest of this case study, we consider price to be a fixed input and focus on the decision of when to discharge and charge to make the most revenue, subject to constraints. The charge/discharge is therefore the quantity of the Price x Quantity that makes up our revenue calculation that we are maximizing. Finally, because charging requires buying energy from the grid and later supplying energy, the optimization captures a simple economic approach: buying energy at the lowest cost and selling it at the highest possible value.

TBn OPTIMIZATION APPROXIMATION

All that said, optimization can be complicated and computationally intensive. Therefore, it is useful to have a rough approximation of how an optimization process works. For battery storage, a common approximation is the TBn method. With this, modelers take the sum of the top n priced hours in a day and subtract the sum of the bottom n priced hours in a day to estimate the revenue you could generate from a BESS project with n hours of duration. The benefit of this method is that it captures the simple economic approach of a battery: buying low and selling high. It also replicates some of the core constraints, namely the limited amount of energy capacity. Finally, it is simple to replicate in Excel, and can serve as an effective indicator of energy price volatility and a high potential energy storage opportunity.

Example: To calculate revenue of a 1MW/2MWh BESS using TBn method, you take the top 2 (T2) priced hours at any point in the day, the bottom 2 (B2) priced hours at any point in the day, and subtract T2 less B2 and apply charge/discharge efficiencies. This method does not ensure SOC feasibility as one of the T2 hours may come at a time when you have no energy in the battery or the B2 hours may come at a time when you have a full state of charge and thus no ability to charge.

CASE STUDY OVERVIEW

We want to estimate TBn revenue of a 1MW/2MWh BESS at HB_NORTH for 2022.

You will find two excel files attached with this case study. *DAM_prices_2022.xlsx* contains hourly prices and *RTM_prices_2022.xlsx* contains 15-min interval prices from Jan 1 to Dec 31, 2022 with the following columns:

Column Name	**Description**
Delivery Date	Date in mm/dd/yyyy format
Delivery Hour	Hour of day from 1 to 24; Hour 1 is 00:00 & Hour 24 is 23:00
Delivery Interval	15-min interval of hour from 1 to 4 (only for RTM Prices)
Repeated Hour Flag	Y represents the repeated hour when local US time jumps from Daylight Savings Time back to Standard Time

Settlement Point	Name of the location
Settlement Point Price	Price in $/MWh

You need to do the following tasks –

1. Create a csv file containing DAM & RTM prices at hourly intervals from Jan 1 to Dec 31, 2022 for HB_NORTH

   The csv file should be named ‘task_1.csv’ with only 4 columns.

Column Name	Description
date	Datetime values in ‘yyyy-mm-dd hh:mm:ss’ format starting from 2022-01-01 00:00:00 to 2022-12-31 23:00:00 in 1 hour increments
repeated_hour_flag	Y / N
dam	Hourly DAM price rounded up to 2 decimal digits
rtm	Hourly RTM price rounded up to 2 decimal digits

   Hourly RTM price is calculated by averaging the four 15-min interval RTM price for a given hour.

2. Create a csv file containing DAM & RTM prices at 15-min intervals from Jan 1 to Dec 31, 2022 for HB_NORTH

   The csv file should be named ‘task_2.csv’ with only 4 columns.

Column Name	Description
date	Datetime values in ‘yyyy-mm-dd hh:mm:ss’ format starting from 2022-01-01 00:00:00 to 2022-12-31 23:00:00 in 15 min increments
repeated_hour_flag	Y / N
dam	15-min DAM price rounded up to 2 decimal digits
rtm	15-min RTM price rounded up to 2 decimal digits

   15-min DAM price is the same as hourly DAM price for all four 15-min intervals in a given hour.

3. Calculate the daily TB2 revenue at HB_NORTH for the following scenarios using the csv files from task #1. Assume that the charge and discharge efficiency is 100%.

Scenario Name	**Description**
Hourly_DA_only	BESS can only participate in DAM and not RTM
Hourly_RT_only	BESS can only participate in RTM and not DAM

Save the output in a csv file containing daily TB2 revenue from Jan 1 to Dec 31, 2022 for HB_NORTH with above two scenarios.

The csv file should be named 'task_3.csv' with only 3 columns.

Column Name	**Description**
date	Date values in 'yyyy-mm-dd' format starting from 2022-01-01 to 2022-12-31 in 1 day increments
da_tb2	Daily TB2 revenue for Hourly_DA_only scenario rounded up to 2 decimal digits
rt_tb2	Daily TB2 revenue for Hourly_RT_only scenario rounded up to 2 decimal digits

4. Calculate the monthly TB2 revenue in $/kW-month units using the csv files from task #3 for both scenarios at HB_NORTH.

Save the output in a csv file containing monthly TB2 revenue. The csv file should be named 'task_4.csv' with only 4 columns.

Column Name	**Description**
month	Date values in 'yyyy-mm-dd' format (where dd=1) starting from 2022-01-01 to 2022-12-01 in 1 month increments
da_tb2	Monthly TB2 revenue for Hourly_DA_only scenario rounded up to 2 decimal digits
rt_tb2	Monthly TB2 revenue for Hourly_RT_only scenario rounded up to 2 decimal digits

Revenue ($/kW-month)

= Sum of daily revenue ($) / (Battery Power Capacity (kW) x Number of months)

5. Calculate the daily TB2 revenue at HB_NORTH using 15-min RTM prices from task #2. Assume that the charge and discharge efficiency is 100%.

   a. Write the step-by-step logic below

   b. Calculate and save the output in csv file as ‘task_5.csv’

6. Calculate the daily TB2 revenue at HB_NORTH assuming charge and discharge efficiency of 95% for Hourly_DA_only scenario.

   a. Write the step-by-step logic below

   b. Calculate and save the output in csv file as ‘task_6.csv’

7. Calculate the daily TB2 revenue at HB_NORTH for Hourly_DART_best scenario. Assume that the charge and discharge efficiency is 100%.

Scenario Name	**Description**
Hourly_DART_best	BESS can participate in both DAM and RTM simultaneously but cannot charge or discharge in both DAM and RTM at the same hour

   a. Write the step-by-step logic

   b. Calculate and save the output in csv file as ‘task_7.csv’

8. TBn method does not ensure SOC feasibility. How can you modify the TBn method to ensure SOC feasibility? Assume that the charge and discharge efficiency is 100%.

   a. Write the step-by-step logic

   b. Calculate the modified TB2 for Hourly_DA_only scenario in task #3 and save the output in csv file as ‘task_8.csv’