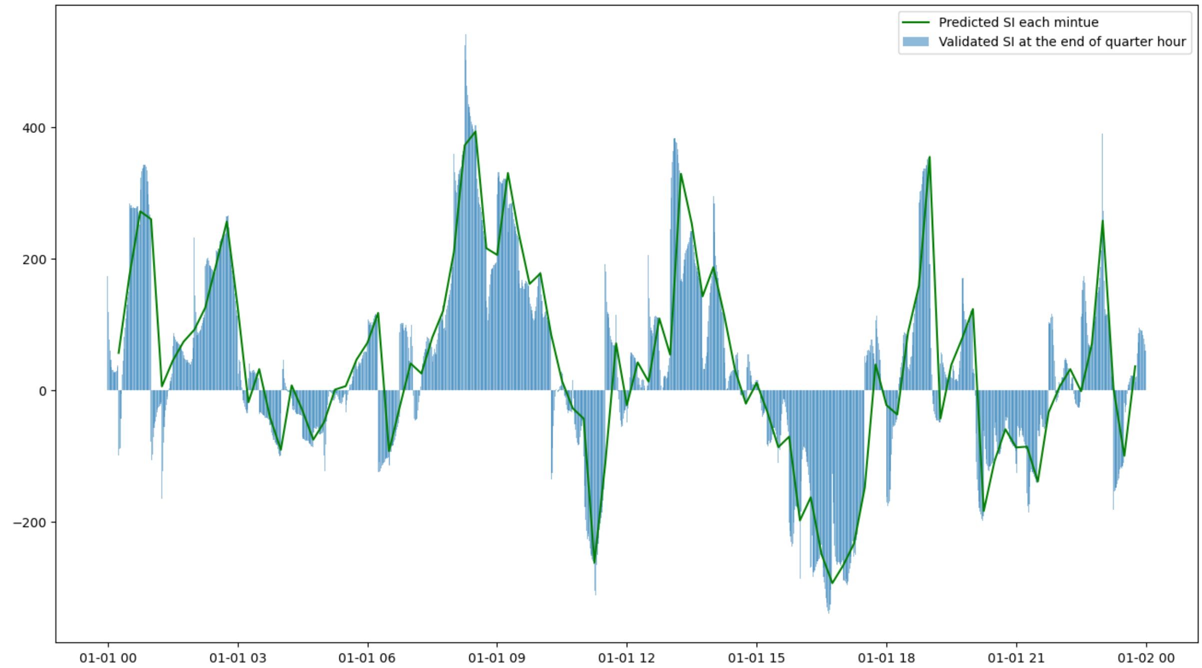
IB models



1 Introduction

The purpose of this document is to explain the functioning of the imbalance market simulation model, used in the Watts.Happening website. Based on the assumptions set out below, the input provided by the user and the data of the imbalance price in Belgium from **01/05/2023 to 30/04/2024**, the model calculates the yearly potential profit/savings of an asset's participation in the imbalance product. These results are displayed in the "Watts.Happening" simulator.

It shall be noted that this is an historical analysis given as an indication. The market context (update of Imbalance Price formula, connection to EU platforms, etc.) has evolved since.

The simulator takes in the constraints of each asset and decides the direction that it would activate for each quarter hour. The simulator then calculates the potential profit for each asset over the year.

Note that the model is limited to one selected asset and market and does not consider the interaction with other assets or flexibility products.

2 User input

The user is required to provide information about:

- Asset Type: determines the behaviour of the asset.
- Average capacity used (Running Set Point): Baseline power, total energy needed per day. Can be used to deduct maximum upward/downward capacity.
- Activation related: duration, frequency, availability ratio
- Asset specific data: minimum power, subsidies, etc.

3 Data sources

1-minute Imbalance publication: Elia Opendata. Cumulative imbalance data per minute is the value of the Imbalance data (System Imbalance, Imbalance Price) given the situation since the beginning of the quarter hour. Validated 15-minute imbalance data: Elia Opendata

Solar, Wind production profile: Elia Opendata

4 Simulated Assets

1. Both upwards and downward flexibility
   - Battery
   - Pump hydro storage
   - Industrial demands
   - Heat pumps
   - Diesel generator
   - WKK-Cogen
   - CCGT
2. Downward only
   - Solar
   - Wind

5 Assumptions and deployed strategy

For simplicity, the asset activates in every quarter hour, reacting only according to the publication of the 1st minute of the quarter hour.

Assumptions:

1. The BRP always starts at a balanced state at the start of the quarter hour (QH).
2. The activation does not affect the overall system imbalance (SI).
3. Activation starts after the decision, until the end of the QH.
4. There is a delay of 2 minutes between the published minute and actual publication time.
5. No correlation between each QH, i.e., only the data from the current QH is considered.
6. If activation duration is limited, the activation window is arbitrary – a predetermined window of hours is selected, with 12pm at the midpoint of the activation window.
7. For storage assets, the state of charge (SoC) starts at the middle of the available charge capacity. In other words, at the start of the simulation, the asset has equal amount of energy to charge and discharge.
8. For storage assets, SoC carries over from each calendar day and each availability period. In other words, the simulation keeps tracks the SoC continuously throughout the year.
9. Asset only participates in the imbalance market and is not participating in other markets. This assumption affects storage assets the most since their activation is limited by SoC and would usually charge up in other markets.
10. No extra activation cost:
    - No grid cost, tariffs and taxes
    - The renewables (with near zero cost or negative cost due to subsidies) don't have curtail threshold originally. they would produce even at negative net gain.
    - No degradation costs
    - No efficiency loss

Activation strategy:

1. Check the value of the published 1 minute imbalance price of the 1st minute (published at 3rd minute, because of the delay of publication)
2. Activate the asset to in the opposite direction, on the 4th minute.
3. Shut down the activation at the 15th minute.

Availability constraints:

1. The user can input daily activation length and daily available period. These two constraints may contradict.
2. To simplify the calculation, whenever available period is specified, it would override the activation length constraints. All the activation in the available periods would be calculated.
3. For storage assets, the availability is limited by the SoC. The asset only activates the amount where the charge/capacity is sufficient

Profit calculation:

1. The asset is activated for every QH segment, for 12 minutes (4th to 15th minute).
2. The ramping speed is calculated as a penalty. The longer the ramping, the lower the total activation energy, the lower the profit.
3. The profit of the QH is calculated with the final validated imbalance prices.
4. The output is the total profit over a year, given the user inputs.
5. To simplify the profit calculation and to reduce the amount of custom inputs, fuel prices are not considered in this market simulation.
6. For battery assets, an average daily discharge cycle is displayed. The value is calculated as the average daily discharged divided by the available charge capacity, instead of the actual maximum charge capacity

6 Profit and Tariff explanation:

The imbalance tariff used in the analysis is explained in the documents: tariff 2023 et tariff 2024. Note that the imbalance tariff has evolved and the applicable imbalance price is explained in the Terms & Conditions BRP.
In summary, the marginal decremental price (MDP) is the main component of the imbalance price when the system is long, and the marginal incremental price (MIP) is the main component when the system is short. Alpha is an extra incentive to balance the grid when the absolute SI is higher than 150 MW.

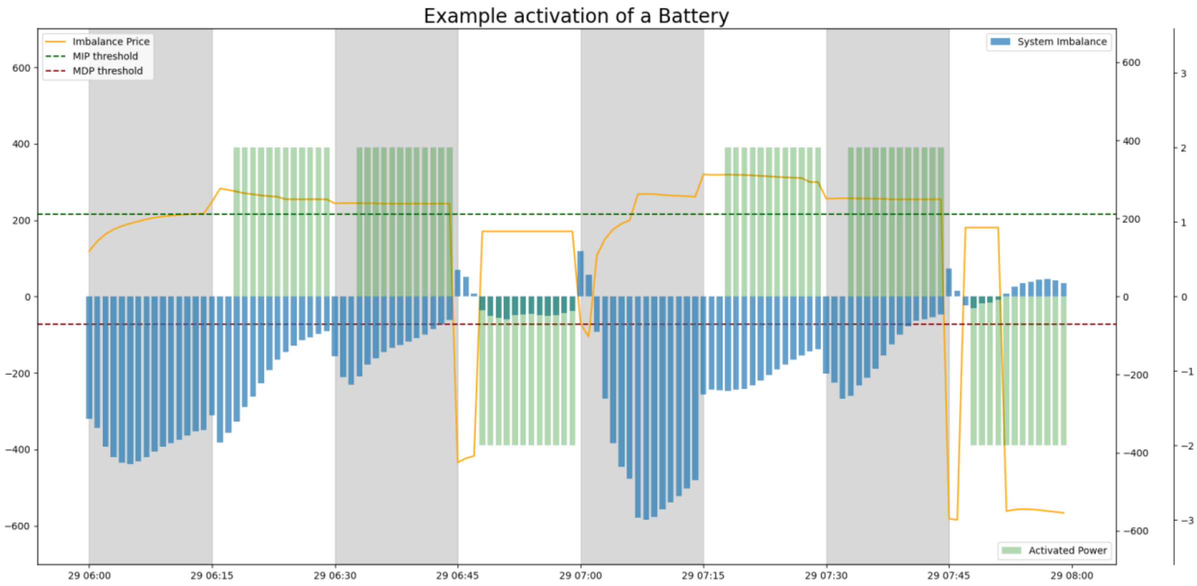
		System Imbalance	
		Positive	Negative or Zero
Imbalance of the BRP	Positive	BRP pays $MDP - \alpha$	BRP receives $MIP + \alpha$
	Negative	BRP receives $MDP - \alpha$	BRP pays $MIP + \alpha$

$MDP - \alpha$ and $MIP + \alpha$ are both signed. In the BRP's profit making point of view, they can always profit by activating the asset to the more beneficial direction according to the imbalance price.

BRPs react accounting the operational cost, opportunity cost and fuel cost. When the system imbalance is positive, the BRP is incentivized to activate downwards. When the system imbalance is negative (or zero), the BRP is incentivized to activate downwards.

7 Example operation

Example 1: battery on 2024-04-29 0600



Asset assumptions:

- 2 MW power capacity
- Effective 4 MWh charge capacity (5 MWh max with 1 MWh reserve), starting the simulation at 50% charge (2MWh)
- At this point of time (2024-04-29 0600) the battery has 50% charge
- Ramp rate 15 sec

Steps:

1. Check the forecasted cost from the 1-minute published data.
2. Because of the delayed information, the data for minute one comes at the 3rd minute
3. The asset aims to activate to balance the grid according to the published SI.
4. The asset checks if the published price passed the threshold. (MIP > 214.8 €/MWh and MDP < -71.5 €/MWh)
5. The asset checks if it has sufficient charge capacity to charge or discharge.
6. The asset activates at the start of the 4th minute if the criteria are met.

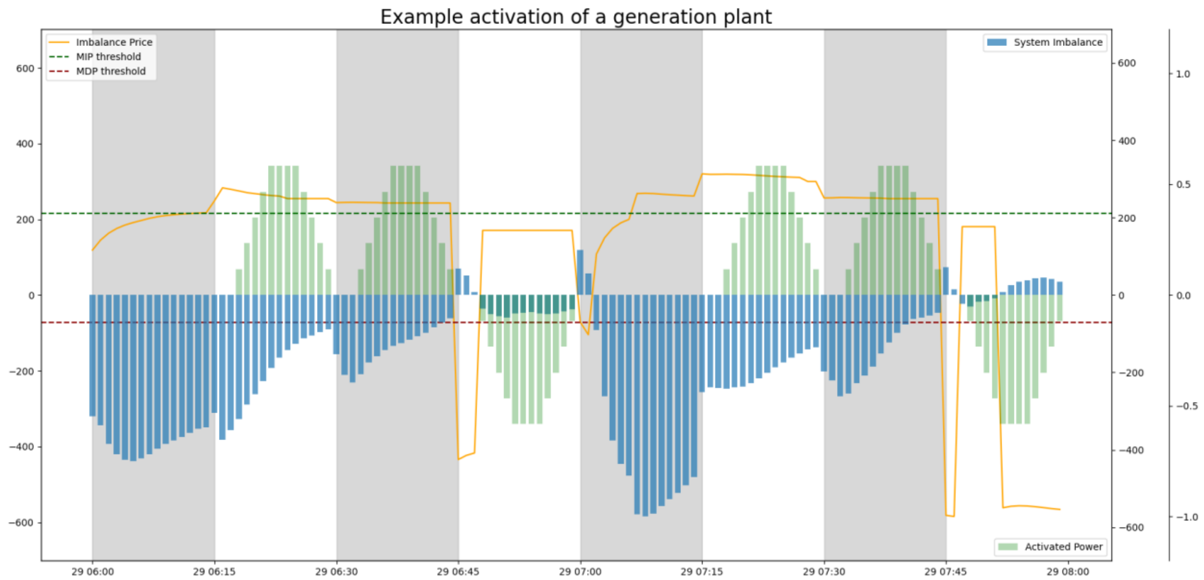
Notes on activation:

1. In the 1st QH, the SI at the first minute is negative, but the price did not pass the threshold
   -> No activation
2. In the 2nd and 3rd QH, the SI at the first minute is negative, and the published price passed the threshold
   -> Activated upward (discharge). Asset profits from discharging.

3. In the 4th QH, the SI at the first minute is positive, and the price passed the threshold (-71.5) -> Activated downward (charge). However, the SI switched sign during the QH and the ending SI is negative, and price is positive. Asset pays for charging.
4. The next 3 QH is similar to the ones in the previous hours.
5. In the last QH, the SI at the first minute is positive, and the price passed the threshold (-71.5) -> Activated downward (charge). Although SI switched during the QH, it is still positive at the 15th minute, and the resulting price is negative. Asset profits from charging.

DateTime	system_imbalance_at_1st	imbalance_price_at_1st	passed_threshold	SoC	imbalance_price	activated_capacity	profit
2024-04-29 06:00:00+00:00	-314.128	118.57	0	2.0	217.52	0.0	0.000
2024-04-29 06:15:00+00:00	-304.244	248.30	1	1.6	254.56	0.4	101.824
2024-04-29 06:30:00+00:00	-152.259	243.98	1	1.2	243.00	0.4	97.200
2024-04-29 06:45:00+00:00	67.576	-434.32	1	1.6	170.60	-0.4	-68.240
2024-04-29 07:00:00+00:00	116.855	-71.13	0	1.6	262.17	-0.0	-0.000
2024-04-29 07:15:00+00:00	-250.419	319.88	1	1.2	299.69	0.4	119.876
2024-04-29 07:30:00+00:00	-198.017	256.28	1	0.8	254.46	0.4	101.784
2024-04-29 07:45:00+00:00	71.707	-581.69	1	1.2	-566.06	-0.4	226.424

Example 2: A WKK Cogeneration plant on 2024-04-29 0600



Asset assumptions:

- A WKK Cogeneration plant
- Maximum activation: 1 MW upward and 1 MW downward
- Ramp speed: 5 minutes to maximum activation

Notes on activation:

1. Similar to the example for the battery, the asset activates according the SI and the price at the first minute of each hour.

2. Since the asset is slower to react, with a ramp rate of 5 minute, the asset starts activation on minute 4 but reach maximum only at minute 8. The asset also started ramping down at minute 12 and reach minimum at the end of minute 15 to prepare for the next QH.

DateTime	system_imbalance_at_1st	imbalance_price_at_1st	passed_threshold	imbalance_price	activated_capacity	profit
2024-04-29 06:00:00+00:00	-314.128	118.57	0	217.52	0.000000	0.000000
2024-04-29 06:15:00+00:00	-304.244	248.30	1	254.56	0.116667	29.698667
2024-04-29 06:30:00+00:00	-152.259	243.98	1	243.00	0.116667	28.350000
2024-04-29 06:45:00+00:00	67.576	-434.32	1	170.60	-0.116667	-19.903333
2024-04-29 07:00:00+00:00	116.855	-71.13	0	262.17	-0.000000	-0.000000
2024-04-29 07:15:00+00:00	-250.419	319.88	1	299.69	0.116667	34.963833
2024-04-29 07:30:00+00:00	-198.017	256.28	1	254.46	0.116667	29.687000
2024-04-29 07:45:00+00:00	71.707	-581.69	1	-566.06	-0.116667	66.040333