mFRR model

1 Introduction

The purpose of this document is to explain the functioning of the mFRR (manual Frequency Restoration Reserve) balancing product simulation model, used in the Watts.happening website. Based on the assumptions set out below (detailed in section 6), and the input provided by the user and the data of the mFRR auction and activation in Belgium from **01/05/2023 to 30/04/2024** (the calculation period), the model calculates the yearly remuneration potential of an asset's participation in the mFRR 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, (connection to EU platforms) has evolved since.

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

2 User input

The user is required to provide information about:

- The maximum power of its asset as well as operating limits, such as the non-flexible part and the running set-point. This information allows the model to define the Upward and Downward Capacity of the asset.
- The Capacity Bidding Price, if any, represents the minimum price below which the asset will not participate in a capacity auction. It is only for upward flexibility.
- The availability of the asset. This input takes into account the availability constraints, due to the asset’s schedule, maintenance or unforeseen events, by means of an Availability factor.
- The Activation Profile the asset follows for the energy activation. The user has the choice between two types of profiles: Balanced and Passive (more information in the section Assumptions).

3 Data sources

All data used in the model are publicly available on Elia’s website or via the Open data platform. To build the model the following data have been used:

- mFRR Capacity Auction results: Capacity - Auction results (elia.be)
    - *Total Awarded Volume mFRR Std* (MW)
    - *Average Price mFRR Std* (€/MW/h)
    - *Marginal Price mFRR Std* (€/MW/h)
- mFRR Available Energy: Data Download Page (elia.be)
    - *Upward Bid Price mFRR Std* (€/MWh)
    - *Upward Bid Price IC* (€/MWh)
    - *Downward Bid Price mFRR D C & D LC* (€/MWh)
- mFRR Activated Volume & Price: Energy - Activated volumes and prices 15 min (elia.be)
    - *Upward regulation volume mFRR Std* (MW)
    - *Upward regulation volume Bids +* (MW)
    - *Downward regulation volume Bids -* (MW)
    - *Incremental Prices mFRR Std* (€/MWh) (capacity + energy bids)
    - *Incremental Prices Bids +* (€/MWh) (energy only)

  - *Decremental Prices Bids* - (€/MWh)
- DA Price: Day-ahead reference price (elia.be)
  - *Reference Price* (€/MWh)

4 Assumptions

Some assumptions are made in order to keep the model from being too cumbersome while still giving relevant results. The model assumes:

- The asset is located in Belgium.
- The model only concerns the Belgian area.
- The model does not take into account the mFRR flex product type.
- The Capacity bid does not impact the *Marginal Price – mFRR Std*
- The Capacity Bid is divisible.
- The Activated Energy does not impact the *Incremental Prices mFRR Std & Bids +* and De*cremental Prices Bids* - (€/MWh)
- The Energy Bidding Price is defined based on the Activation Profile. The model assumes two Activation Profile: Balanced and Passive:
  - The Passive profile: the asset is placed low in the merit order of energy activation, which means that it is rarely selected by Elia. For upward flexibility, the value of this price was set at the 90th percentile of the merit order, while for downward flexibility it was set at the 10th percentile. These thresholds may be subject to change based on user feedback.
  - The Balanced profile is considered to be in the middle of the merit order of energy activation. For upward and downward flexibility, the value has been set to the median price of the merit order.
- For downward flexibility, the merit order of energy activation is composed of D C & D LC bids as published on Elia's website. The model doesn't consider D C Energy-Limited bids. More info : Energy - Available volumes and prices (elia.be)
- If the Capacity bid is not rewarded and then the Allocated Volume equals 0, we assume that the asset will participate as a free bid in the Energy market.
- The Energy Bid is divisible.
- As the model aims to show the gains from participating to a flexibility product, it was decided to translate the Energy Remuneration into Energy Cost Savings. To do so, the model assumes that the Activated Energy is paid at the *Decremental Price Bids –* instead of the *Reference Price* which allow the asset to save cost on its energy.
- 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
- Additional battery assumptions:
  - Since it is not realistic for a battery to reserve all its charge capacity in the mFrr market, there is additional restrictions based on the ratio of the charge capacity and max power.
    - Battery depth <= 1h: Not suitable for mFrr market
    - Battery depth between 1h and 2h: 50% of power capacity to participate
    - Battery depth between 2h and 3h: 90% of power capacity to participate

        - Battery depth > 4h: 100% of power capacity to participate (no restriction).
- Additional renewable assets assumptions:
  Renewable assets (solar and wind) are simulated based on its full installed capacity. Due to the intermittency of renewables, additional assumptions are made to compensate the load factor of the assets.
    - Solar:
        - Only hours 8 to 16 during the day are simulated.
    - An average capacity factor of 27% was observed during the simulation period, at hours 8 – 16. A 27% correction factor is applied to the end results.Wind:
        - An average capacity factor of 23% was observed during the simulation period. A 23% correction factor is applied to the end results.

Some of these assumptions will change as the model evolves.

5 Model

The model works in two stages. Firstly, it calculates the Capacity Remuneration and secondly the Energy Remuneration.

5.1 Capacity Remuneration

The calculation of the Capacity Remuneration consists in four steps:

- The **first step** is to simulate a Capacity bid for all auctions of the calculation period in which the asset can participate based on its availability.
    - As Elia is only reserving capacity for upward flexibility, to calculate the volume of Capacity bid, the model only takes the Upward Capacity of this asset.
    - No Capacity bid will be created for auctions that are part of the unavailability periods mentioned by the user.
- The **second step** is to take account of the asset's activation constraints. There are two of these, Activation Frequency and Activation Time. The constraint on Activation Frequency aims to apply a filter on the day on which the asset will participate in flexibility, while the constraint on Activation Time consists of applying a second filter on the hours of participation of the days selected in the previous filter.
    - For the Activation Frequency, there are 4 possibilities:
        - Every day: in which case no additional constraints are applied. All the days will be taken into account by the model for the next step, except for unavailability periods mentioned by the users in the previous step.
        - Max once a week: for this, the model will select only one day per week and the remuneration will be calculated solely on that day. It selects the day with the highest average *daily price* of the week.
        - Max once a month: In this case, the model applies the same logic as for max once a week, but this time takes just one day per month.
        - Max once a year: In this case, the model applies the same logic as for the maximum once a week, but this time it is a single day over the whole calendar year.
    - For the Activation Time, the model considers 3 possible cases.
        - 15min: In the case of the FCR product, the minimum Activation Time to participate in the flexibility product is 1 hours. For an Activation Time under 1 hours, the model considers that the asset does not meet the product's prerequisites and therefore cannot receive any remuneration.

        - 1 hour; 2 hours; 4 hours; 8 hours; 12 hours: the model considers respectively one, two or three periods with the *highest local marginal capacity price* of the day. The other periods will not be considered when calculating the remuneration.
        - No limitation: the model does not apply a filter to the days. All periods are taken into account.
- The **third step** is to define for each auction period whether the Capacity Bid is rewarded or not based on the Capacity Bidding Price:
    - First the model defines the Capacity Bidding Price. This price is set by default according to the type of asset selected. However, the user has the possibility to enter a price constraint. If this is the case, the model considers the Capacity Bidding Price as this price constraint.
    - Then, for each CCTU, the model checks whether the Capacity Bidding Price is bigger than the *Marginal Price* of mFRR Flex:
        - If so, the model considers the Capacity bid as rewarded. It means the Allocated Capacity is equals to the Capacity bid. However, Allocated Capacity cannot be greater than *Total Awarded Volume* of the tendering period.
        - If not, the model considers the Capacity bid as not rewarded. So, the Allocated Capacity equals 0 MW.

- The **fourth step** consists in calculating the Capacity Remuneration of the asset for the calculation period.
    - For mFRR, as it is pay-as-bid remuneration, the model must define the price of the bid. For each CCTU of the calculation period, the model takes the maximum between 70% of the *Average Price* and the Capacity Bidding Price and multiplies it by the Allocated Capacity to get Capacity Remuneration of the asset.
    - In addition, the model also applies an Availability factor to the Capacity Remuneration in order to take into account possible unavailability of the asset due to maintenance or unforeseen events. This Availability factor is set at 100% by default but can be modified by the user.

5.2 Energy remuneration

The calculation of the Energy Remuneration is done in six steps:

- The **first step** is to define the Energy Bidding price of the asset for each quarter hour of the year. This price is defined according to the Activation Profile chosen by the user and whether the asset has Allocated Capacity for the concerned quarter-hour.
    - For upward flexibility:
        - For the Balanced profile, if Allocated Capacity is not null, the Energy Bidding price will be equal to the median price of all the *Upward Bid Price mFRR Std* available for the quarter hour in question. If Allocated Capacity is null, the Energy Bidding price is equal to the median price of all the *Upward Bid Price IC* available for the quarter hour in question.
        - For the Passive profile, if Allocated Capacity is not null, the Energy Bidding price is equal to the 90th percentile of all the *Upward Bid Price mFRR std* available for the quarter hour in question. If Allocated Capacity is null, the

Energy Bidding price is equal to the 90th percentile of all the *Upward Bid Price IC* available for the quarter hour in question.

- For downward flexibility:
  - If it is the Balanced profile, the Energy Bidding price is equal to the median price of all the *Downward Bid Price* available for the quarter hour in question.
  - If it is the Passive profile, the Energy Bidding price is equal to the 10th percentile of all the *Downward Bid Price* available for the quarter hour in question.

- The **second step** is to apply two filters.
  - The first filter consists of removing periods that are part of asset unavailability periods explicitly mentioned by the user.
  - The second filter consists of applying the same filtering rules as for Capacity Remuneration as a function of Activation Frequency and Activation Time. In other words, the model calculates the Energy Remuneration only for the periods selected following this filtering.
- The **third step** consists in comparing, for each quarter of an hour, the Energy Bidding Price with activation prices depending on the type of product.
  - For upward flexibility:
    - The model first checks whether the asset has Allocated Capacity for this quarter-hour.
      - If this is the case, it will compare the Energy Bidding Price with *Incremental Price mFRR std*. If the Energy Bidding Price is lower, then the asset is considered has activated for that quarter of hour. Otherwise, the model considers the Activated Energy as zero.
      - If not, it compares the Energy Bidding Price with *Incremental Price Bids +*. If Energy Bidding Price is lower, then the asset is considered to be activated for that quarter of an hour. Otherwise, the model considers the Activated Energy as zero.
  - For downward flexibility:
    - The model compares the Energy Bidding Price with *Decremental Prices Bids -*. If the Energy Bidding Price is higher, then the asset is considered to be activated for that quarter of an hour. Otherwise, the model considers the Activated Energy as zero.
- The **fourth step** is to determine the Activated Energy.
  - For upward flexibility:
    - If the asset is considered as activated in the previous step and depending on whether Allocated Capacity is null or not, the model will respectively define the Activated Energy as the minimum either:
      - between Allocated Capacity or and the *Upward regulation volume mFRR Std* or;
      - between Upward Capacity and *Upward regulation volume Bids +.*
  - For downward flexibility:
    - If the asset is considered as activated in the previous step, the model will define the Activated Energy as the minimum between Downward Capacity and *Downward regulation volume Bids -.*
- The **fifth step** consists in calculating the Energy Remuneration.
  - For upward flexibility energy:

  - As it is pay-as-clear market for energy, the model multiplies the Activated Energy by either:
    - *Incremental Price mFRR std*, if Allocated Capacity is not null, or;
    - *Incremental Price Bids +*, if Allocated Capacity is null.
- For downward flexibility energy:
  - As it is pay-as-clear market for energy, the model multiplies the Activated Energy by *Decremental Price Bids -*.
- In addition, the model also applies an Availability factor to the Energy Remuneration in order to take into account possible unavailability of the asset due to maintenance or unforeseen events. This Availability factor is set at 100% by default but can be modified by the user.
- For information, the following convention is applied to the payment for balancing energy:

	Balancing energy price positive	Balancing energy price negative
Upward flexibility energy	Payment from Elia to Asset	Payment from Asset to Elia
Downward flexibility energy	Payment from Asset to Elia	Payment from Elia to Asset

- The **last step** is the calculation of Energy Difference Cost:
  - This step is to compensate the difference between upward and downward activation energy. The cost of the energy difference is determined based on the net position over the year, and which type the asset is.
  - Storage and Load asset: These two types of assets try to maintain net 0 in activation. They will compensate the energy difference in the day-ahead market.
    - Net upward activation: the asset buys the insufficient energy at the 20th percentile price of the day-ahead market
    - Net downward activation: the asset sells the excess energy at the 80th percentile price of the day-ahead market
  - Producer asset: the cost of producing is the LCOE and is provided as a user input.
  - Renewables: Only downward activation and there is no cost for activation (curtailing)

6 Output

The model generates the following outputs:

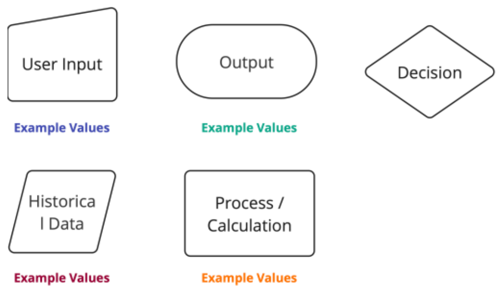
- For the capacity:
  - The Capacity Remuneration for Upward Capacity as described hereabove. It is expressed in € per year.
  - The Bid Allocation Percentage indicates to which extend the Capacity bid is considered as Allocated Volume by the model. If it equals 100%, it means that the asset capacity is rewarded for every auction in which it participates.
- For the energy:
  - The Energy Remuneration for Upward Energy Activation and Downward Energy Activation as described hereabove. It is expressed in € per year.
  - The Energy Activation Percentage indicates the proportion of energy the asset is activated to provide flexibility with respect to the maximum available flexible

energy. 100% means that the asset is offering flexibility at **full power** all the time, while 0% means that it has never been activated.

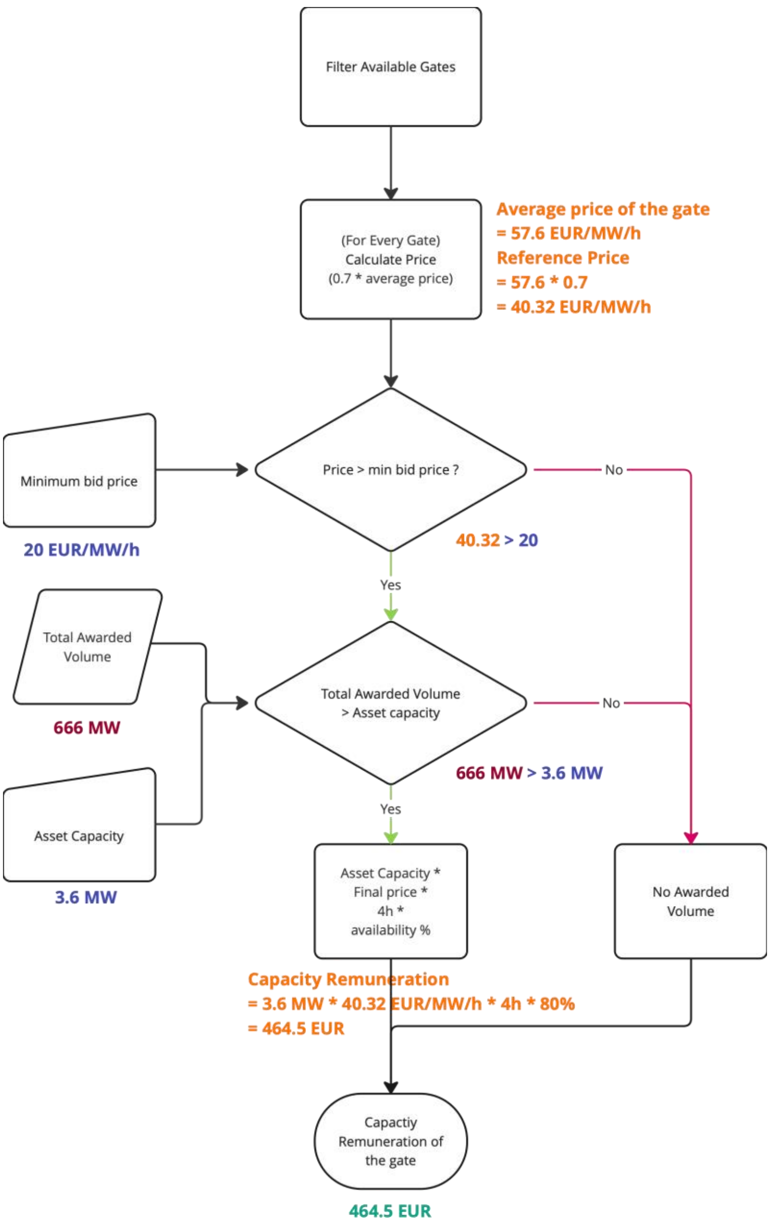
- The Gross Margin is the total potential benefit of participating in the market. It is the addition of the Total Capacity Remuneration and Total Energy Remuneration subtracting the Energy Difference Cost.
- If the asset is a storage asset, an Average Daily Cycle is also calculated. The value is calculated as the average daily discharged divided by the available charge capacity. Note the denominator is the available part instead of the actual maximum charge capacity.

7 Example Calculation

The following shows an example of a battery asset at 2023/05/01
Upward and Downward capacity = 4 MW
Charge capacity = 12 MWh
Due to battery power reserve assumptions, a 3-hour battery would only have 90% of the max power capacity participate in mFrr. Therefore, the power capacity used in the calculation is 3.6MW.



Upward Capacity Remuneration Example 2023/10/15 00h-40h



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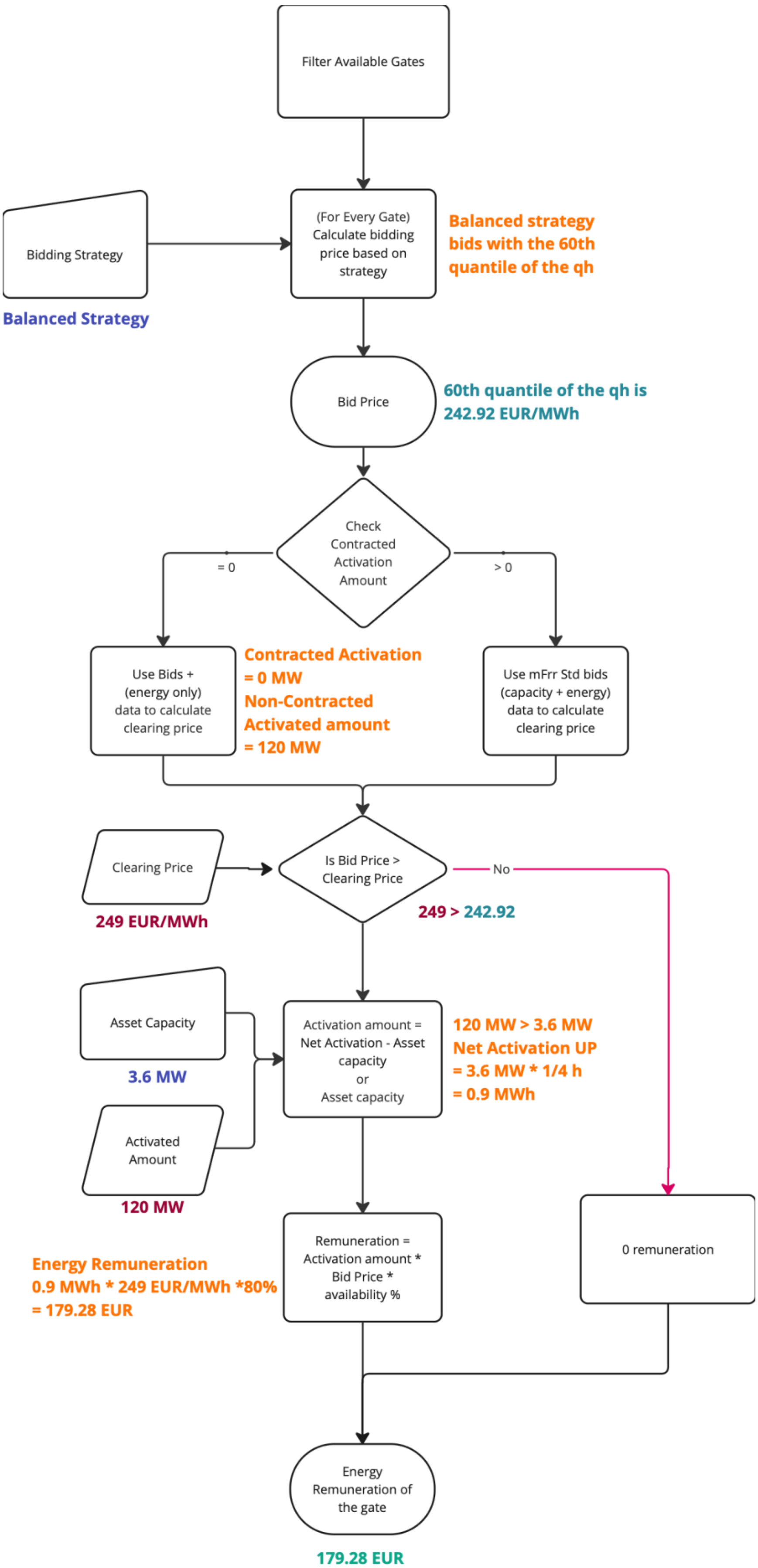
Upward Energy Remuneration Example 2023/08/19 04:30



Last update: 14/05/2025