Battery Ageing • Battery Models • Battery Diagnostics • Battery Pack Design • Charging Infrastructure • Electromobility • Stationary Energy Storage • Energy System Analysis

Developing a battery index for Germany

get enspired! 2024 - Vienna

10-Sep-24

Jonas van Ouwerkerk, Jonas Brucksch, Dirk Uwe Sauer

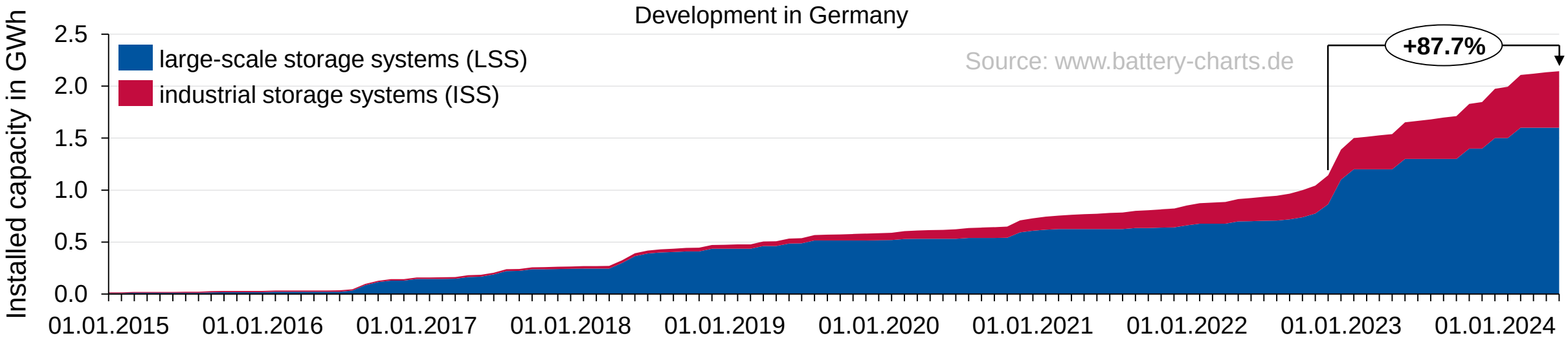
enspired

E.ON Energy Research Center | RWTH AACHEN UNIVERSITY

Center for Ageing, Reliability and Lifetime Prediction of Electrochemical and Power Electronic Systems (CARL)

CARL Center for Ageing, Reliability and Lifetime Prediction of Electrochemical and Power Electronic Systems | iSEA Power Electronics and Electrical Drives | RWTH AACHEN UNIVERSITY

Why a new battery index?



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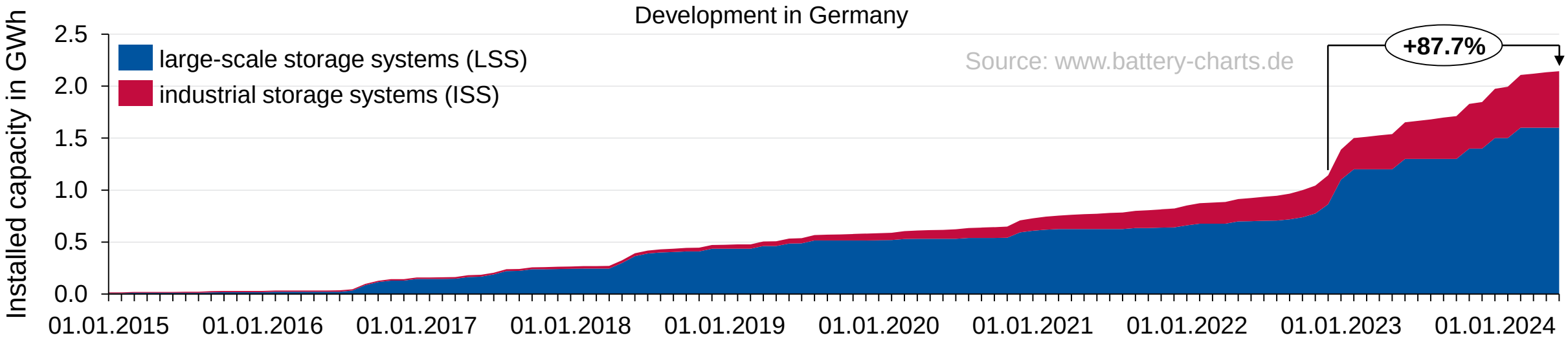

- Market for BESS matures → strong market growth in Germany
- More and more “optimizers” enter market, claiming that their product is the best performing

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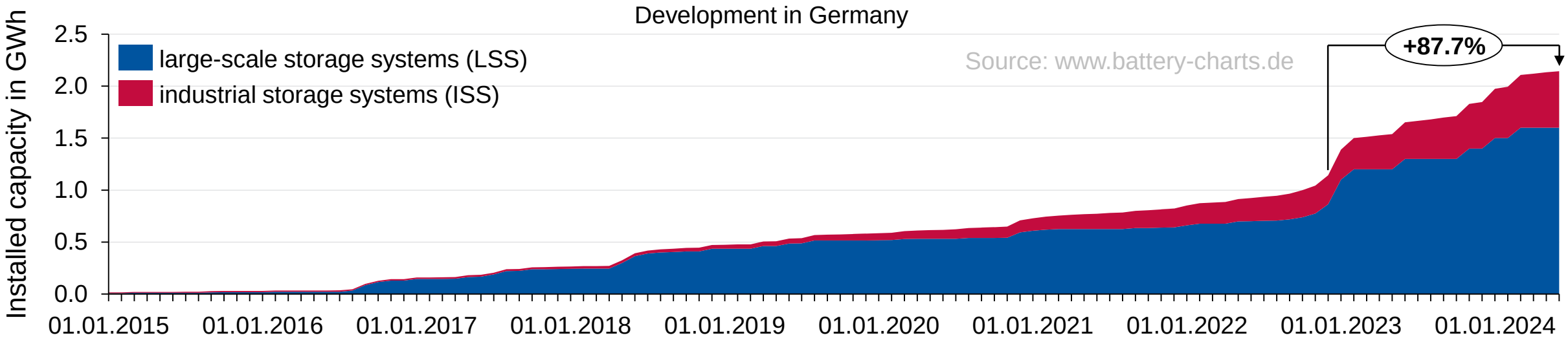
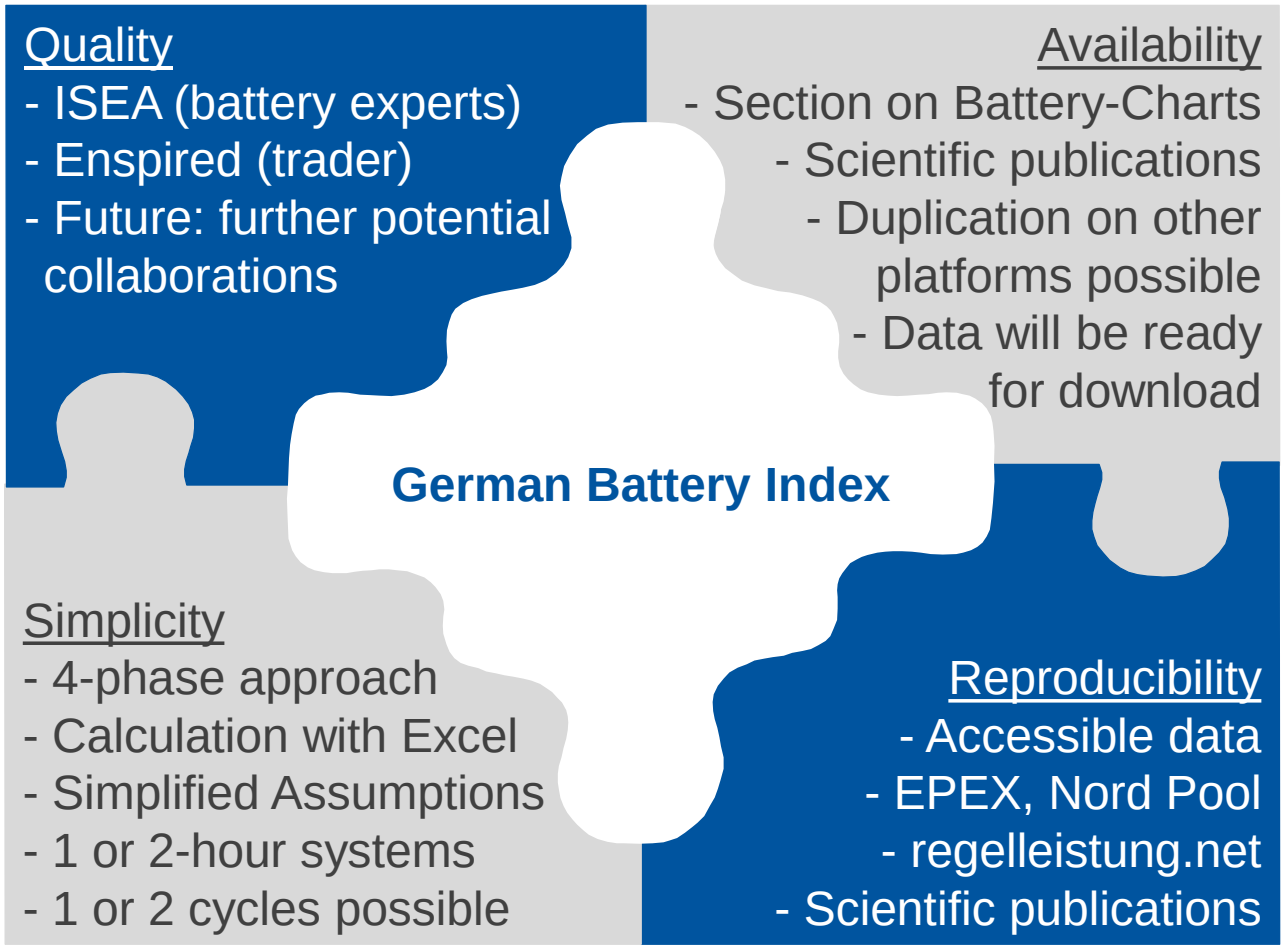


- Market for BESS matures → strong market growth in Germany
- More and more “optimizers” enter market, claiming that their product is the best performing
- Existing battery indexes: complex procedure that cannot be easily replicated
- For developers and investors fact checking of value-stacking products remains difficult
  - Transparency needed!
  - Sophisticated battery index that is “easy to understand” as a benchmark

Overall requirements for a sophisticated battery index



Considered markets

Overall requirements for a sophisticated battery index

German Battery Index

Quality
- ISEA (battery experts)
- Enspired (trader)
- Future: further potential collaborations

Availability
- Section on Battery-Charts
- Scientific publications
- Duplication on other platforms possible
- Data will be ready for download

Simplicity
- 4-phase approach
- Calculation with Excel
- Simplified Assumptions
- 1 or 2-hour systems
- 1 or 2 cycles possible

Reproducibility
- Accessible data
- EPEX, Nord Pool
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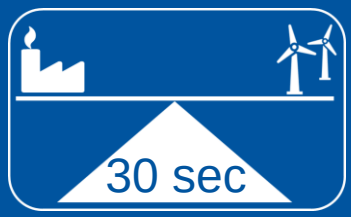
- Scientific publications

Considered markets

FCR
Frequency Containment Reserve



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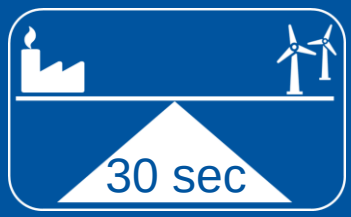

aFRR
Automatic Frequency Restoration Reserve

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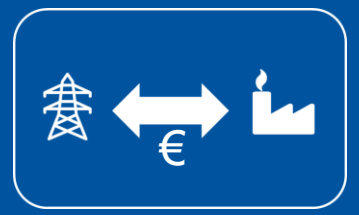
Day-ahead auction (DA)



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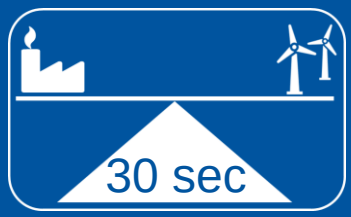

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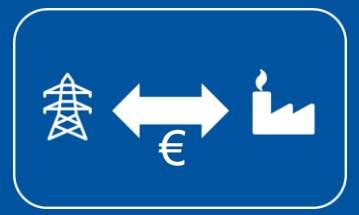

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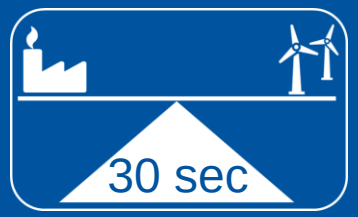
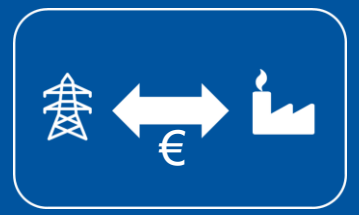


Intraday auction (IA) & continuous (IDC)



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Index development: configurations of battery storage system

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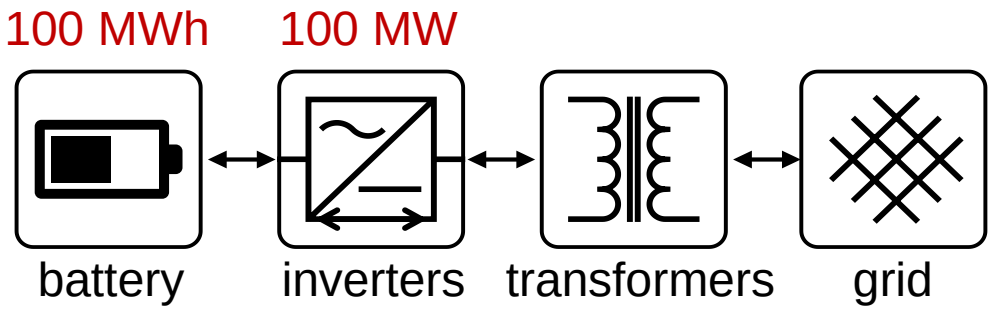

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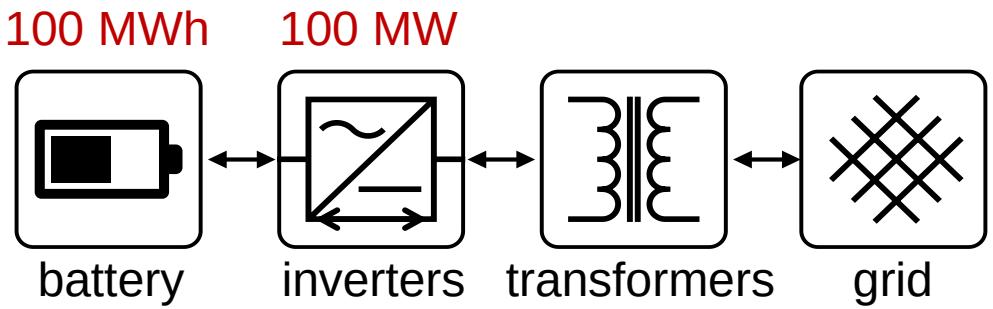

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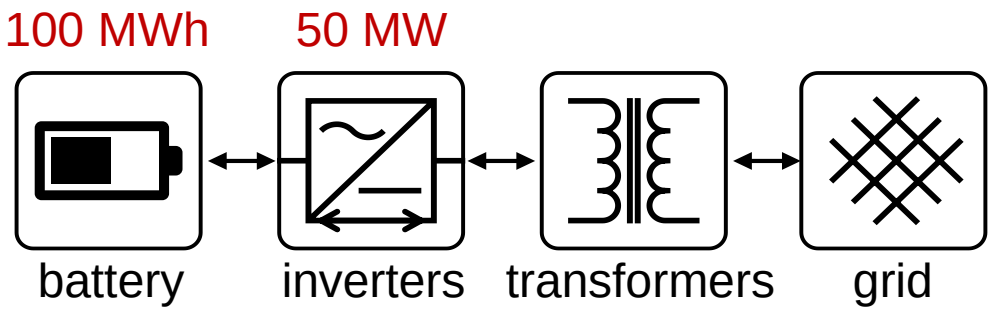

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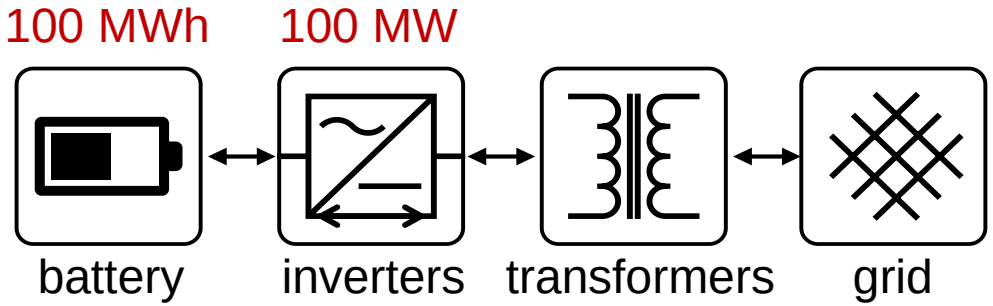

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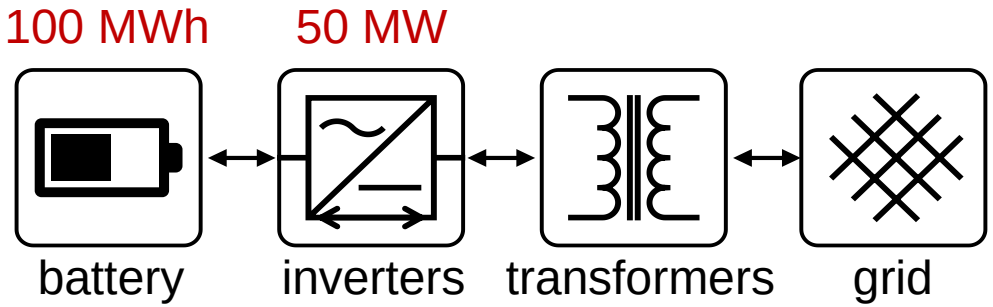

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- Most system today: lithium-iron-phosphate (LFP)
  - Cycle-life: guarantees of 10.000 equivalent full cycles (EFC)
  - Assumption: 1-2% capacity degr./year : 10-20 years lifetime
  - 10.000 EFC / (10 years * 365 days) = 2.73 EFC/day
  - 10.000 EFC / (20 years * 365 days) = 1.37 EFC/day

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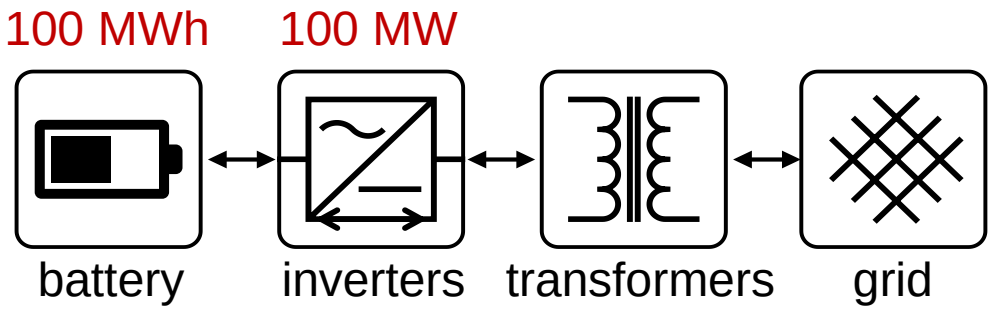

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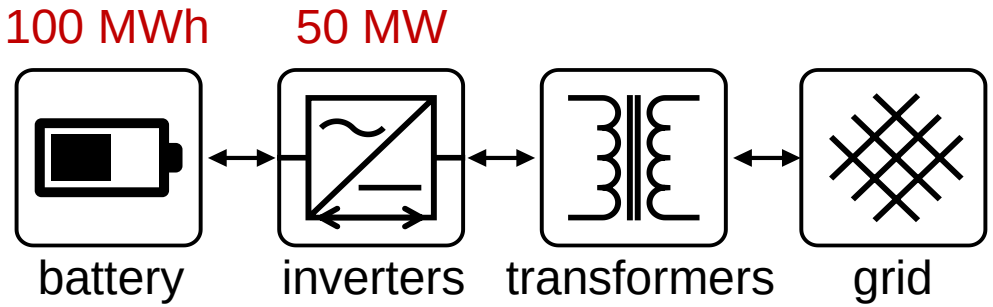

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considered configurations

- 1 hour / 1 cycle
- 1 hour / 2 cycle
- 2 hour / 1 cycle
- 2 hour / 2 cycle

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Aim: single markets revenue potentials

Single markets
No financial trades
aFRR/FCR: capacity only

PHASE 1.5

Combining markets
simple weighting

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Aim: combined market revenue potentials

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Block approach
Physical boundaries
Fixed parameters

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Aim: sophisticated cross-market index

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aFRR: capacity/energy

Variable time steps
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PHASE 4

Aim: validating index with real asset

Validation of index
Real asset
M5BAT or other

Loss factors
Operational constraints

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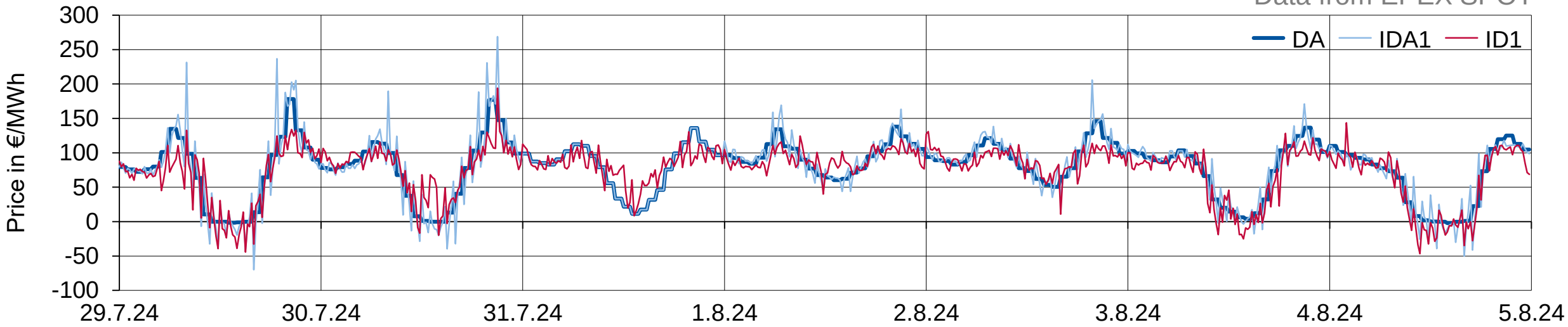
PHASE 1: using exemplary week for proof of concept (KW31, 2024)

Data from EPEX SPOT



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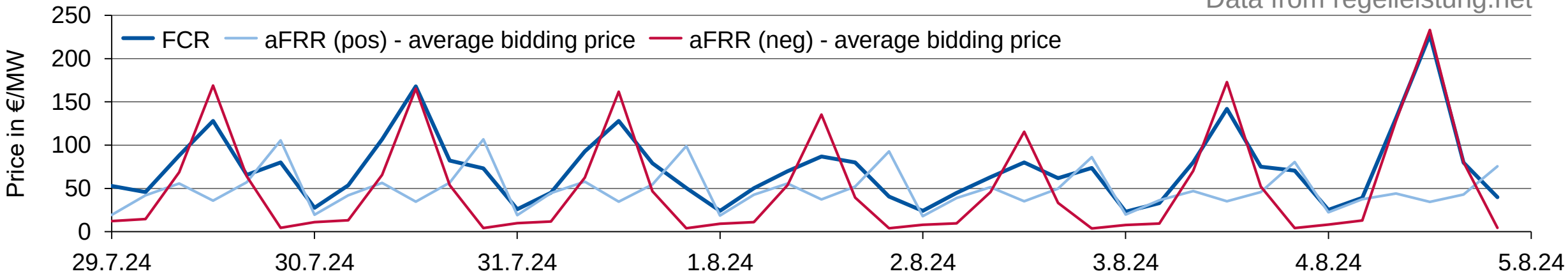

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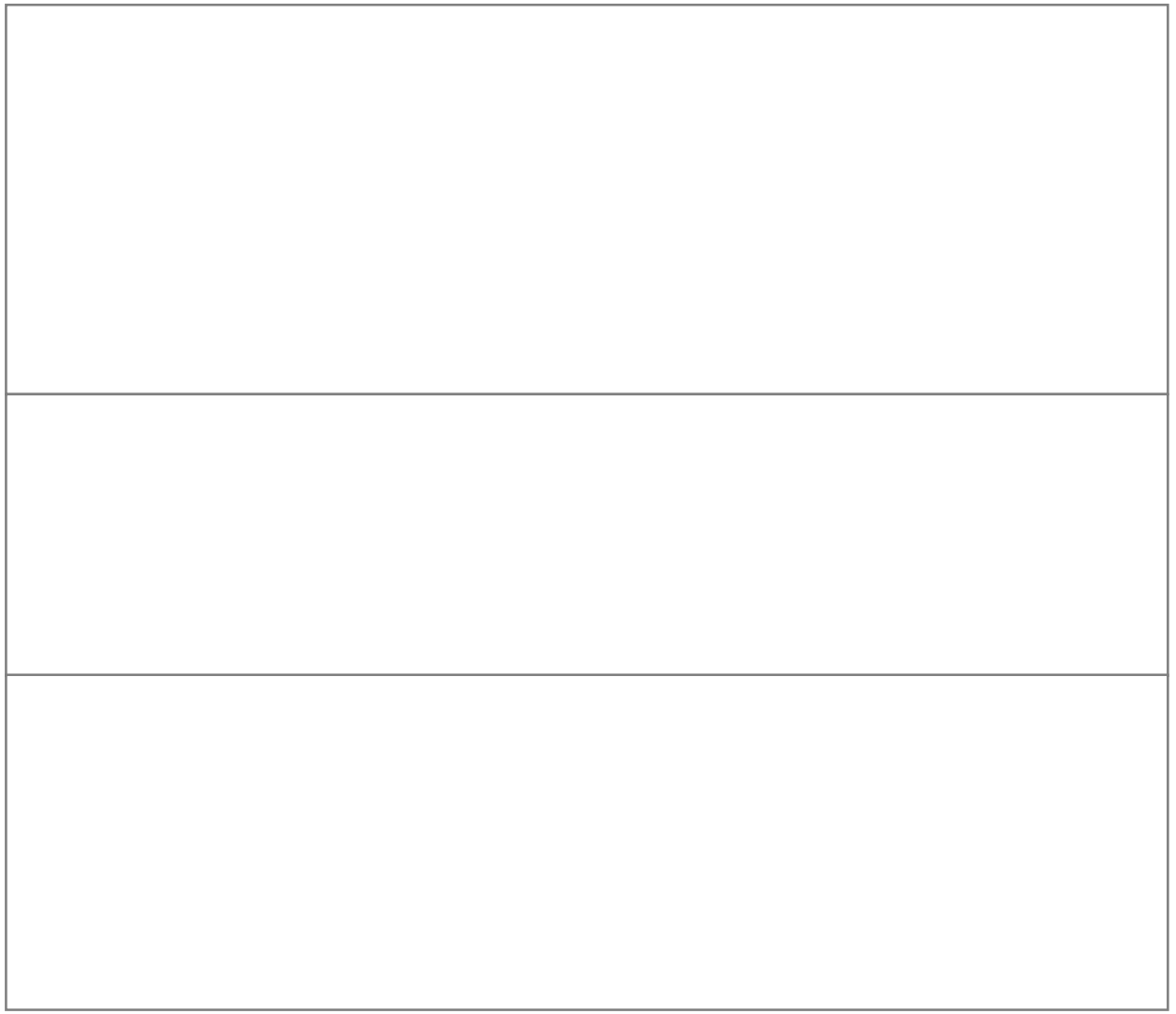
PHASE 1: Day-ahead market approach (1h-system, 2 cycles)



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ordered list of trade pairs
(576 combinations)

Trade	Buy (h)	Sell (h)	Spread (€/MW)	Take?
1	**4**	**12**	**100**	**yes: 1st**
2	4	8	50	no
3	13	16	30	yes: 2nd
...	...	...	...	...
576	23	24	-50	no

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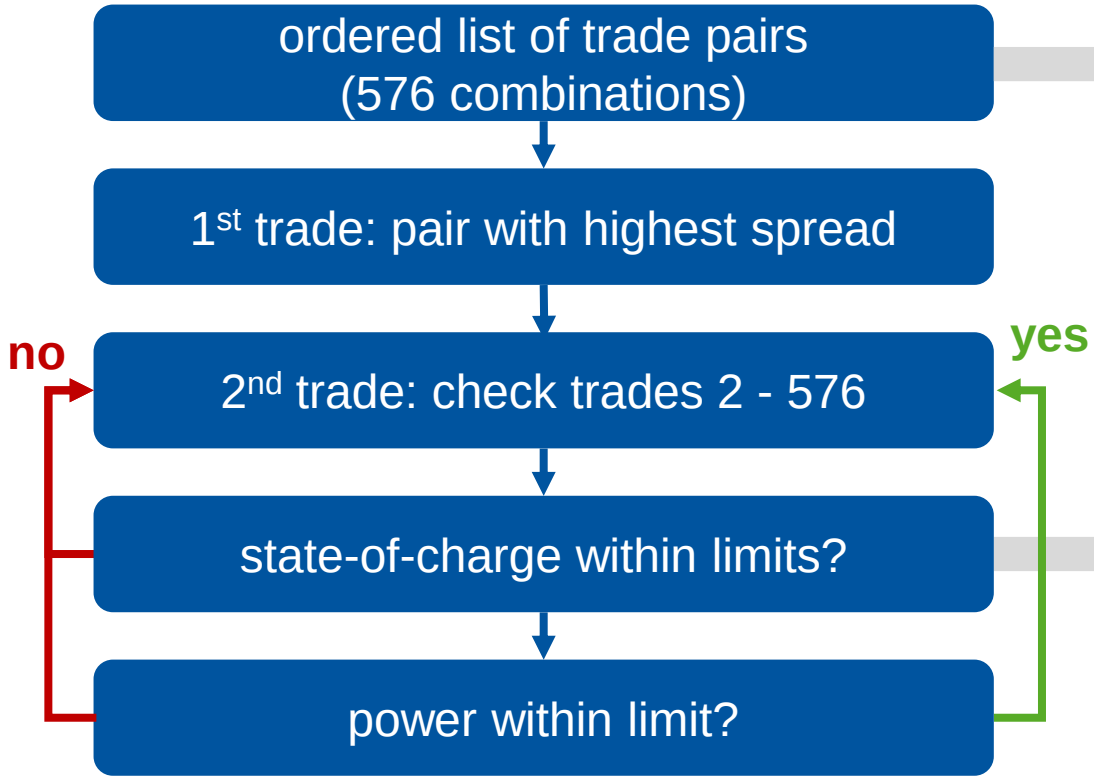

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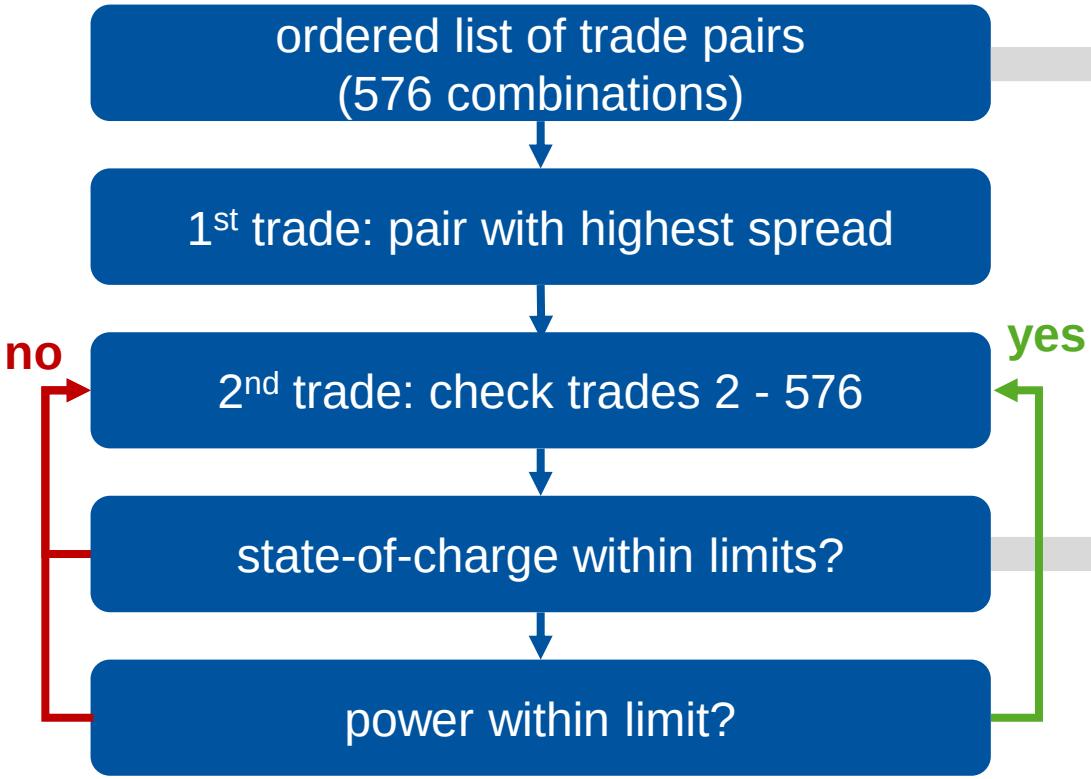

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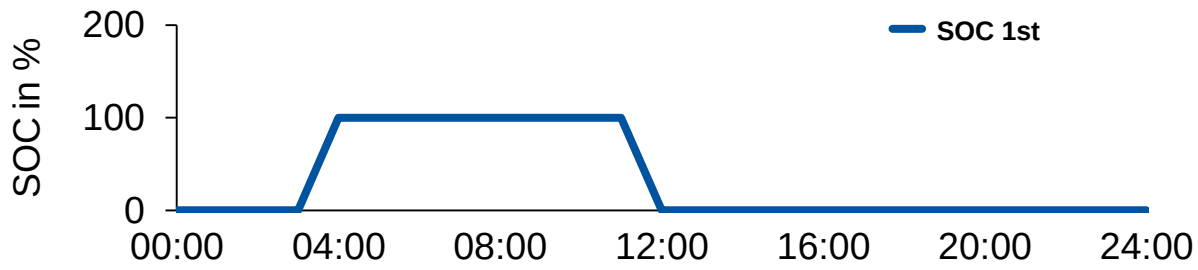

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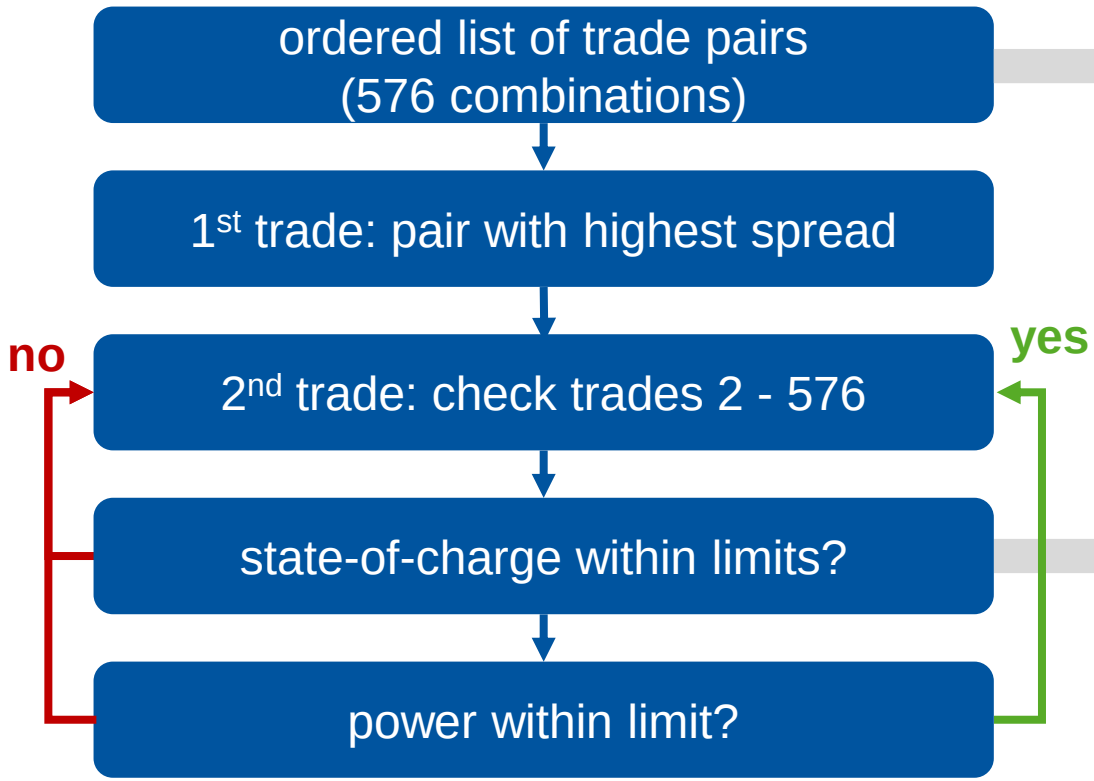

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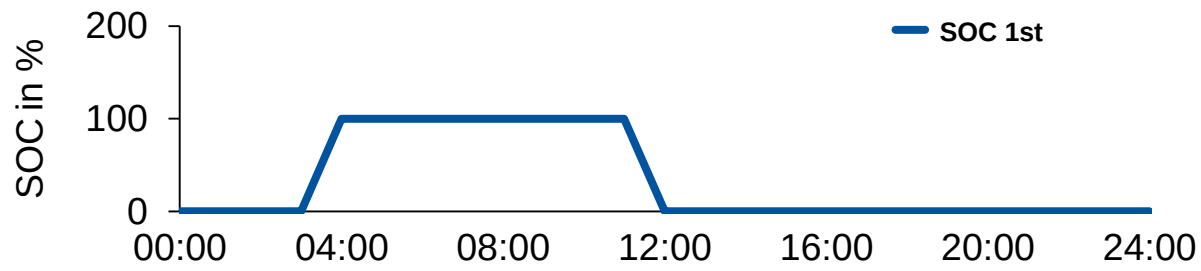

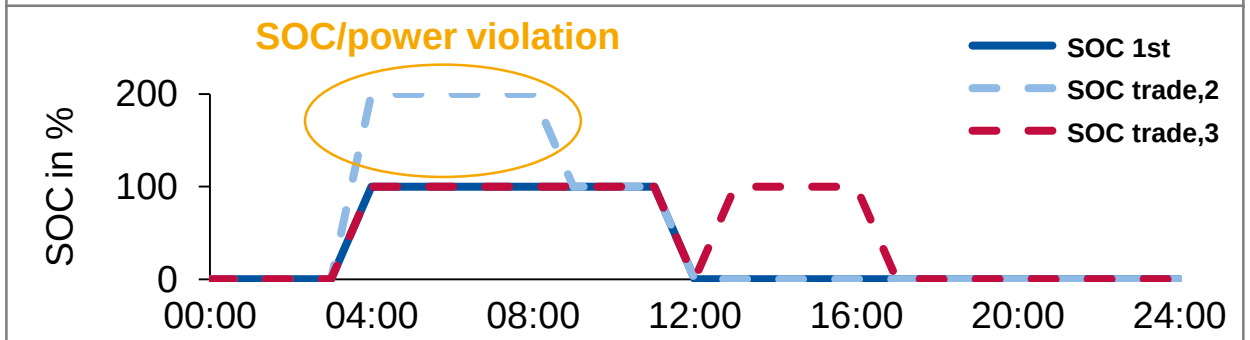

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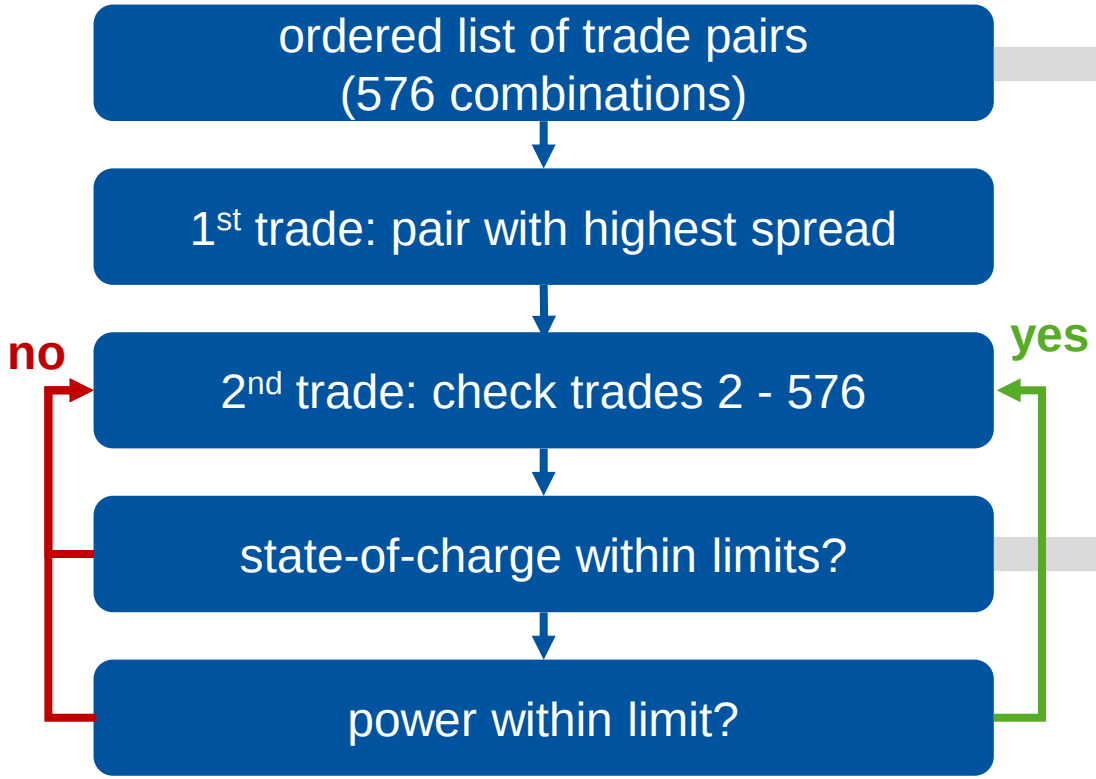

→ Excel sheet with calculation will be provided

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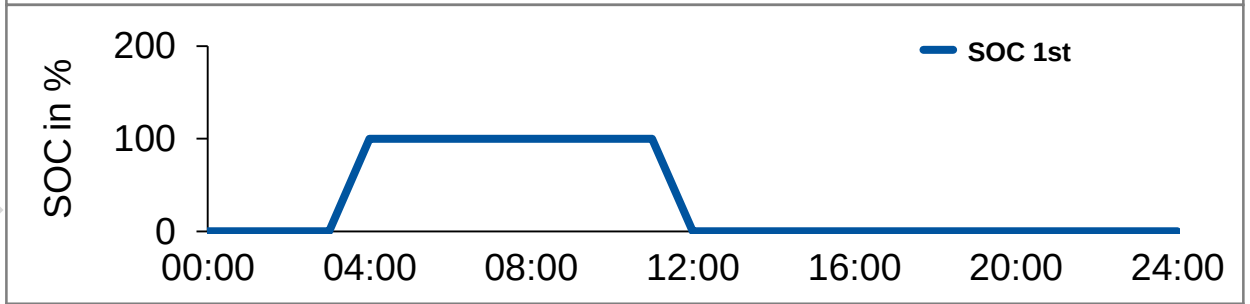

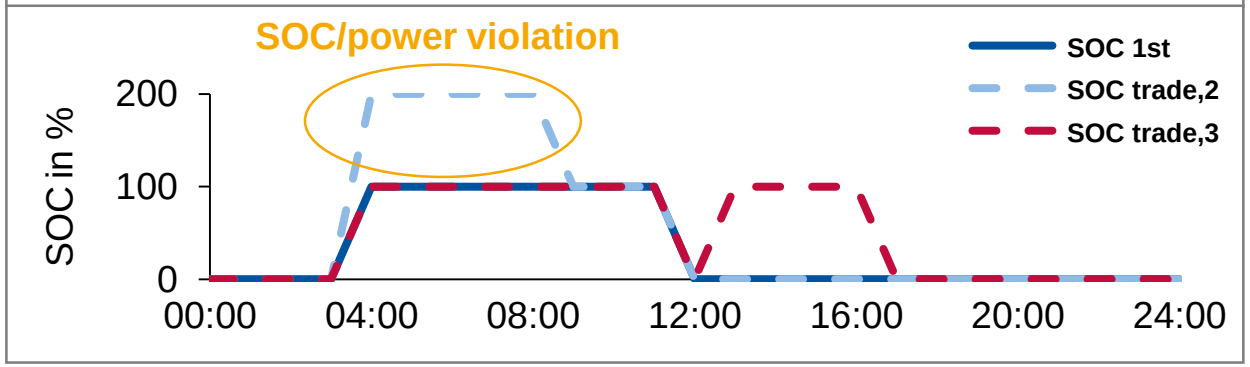

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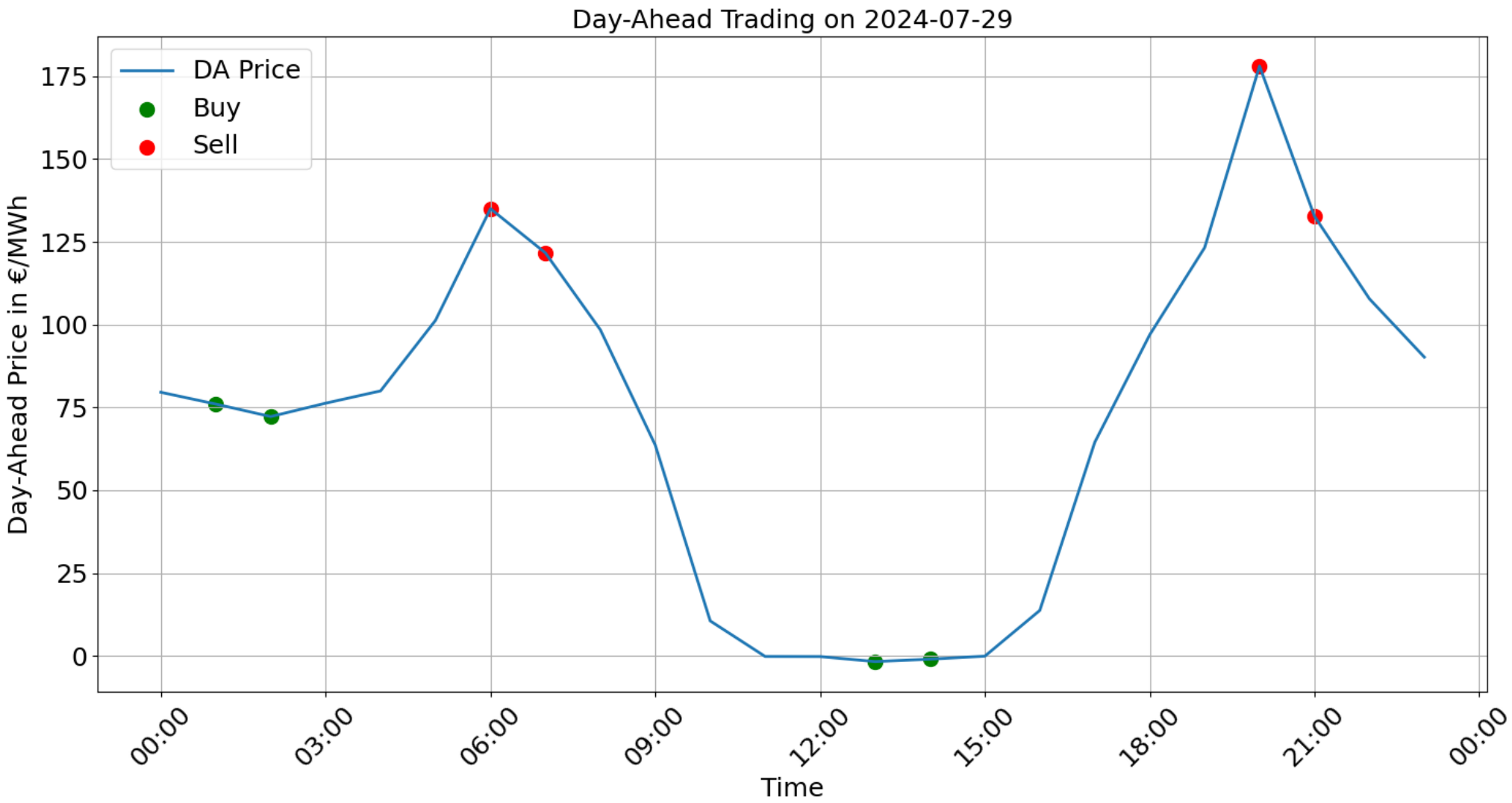

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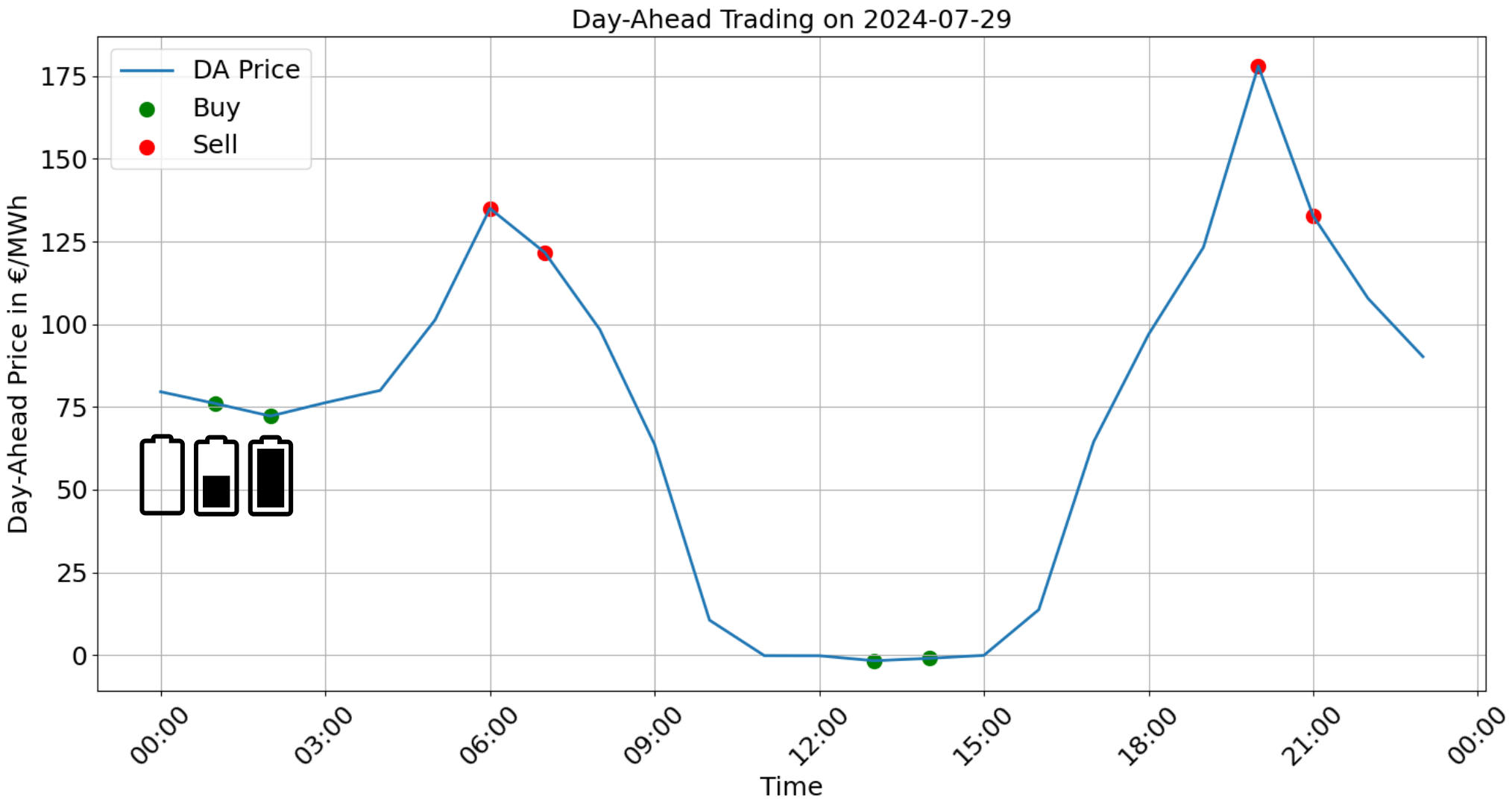

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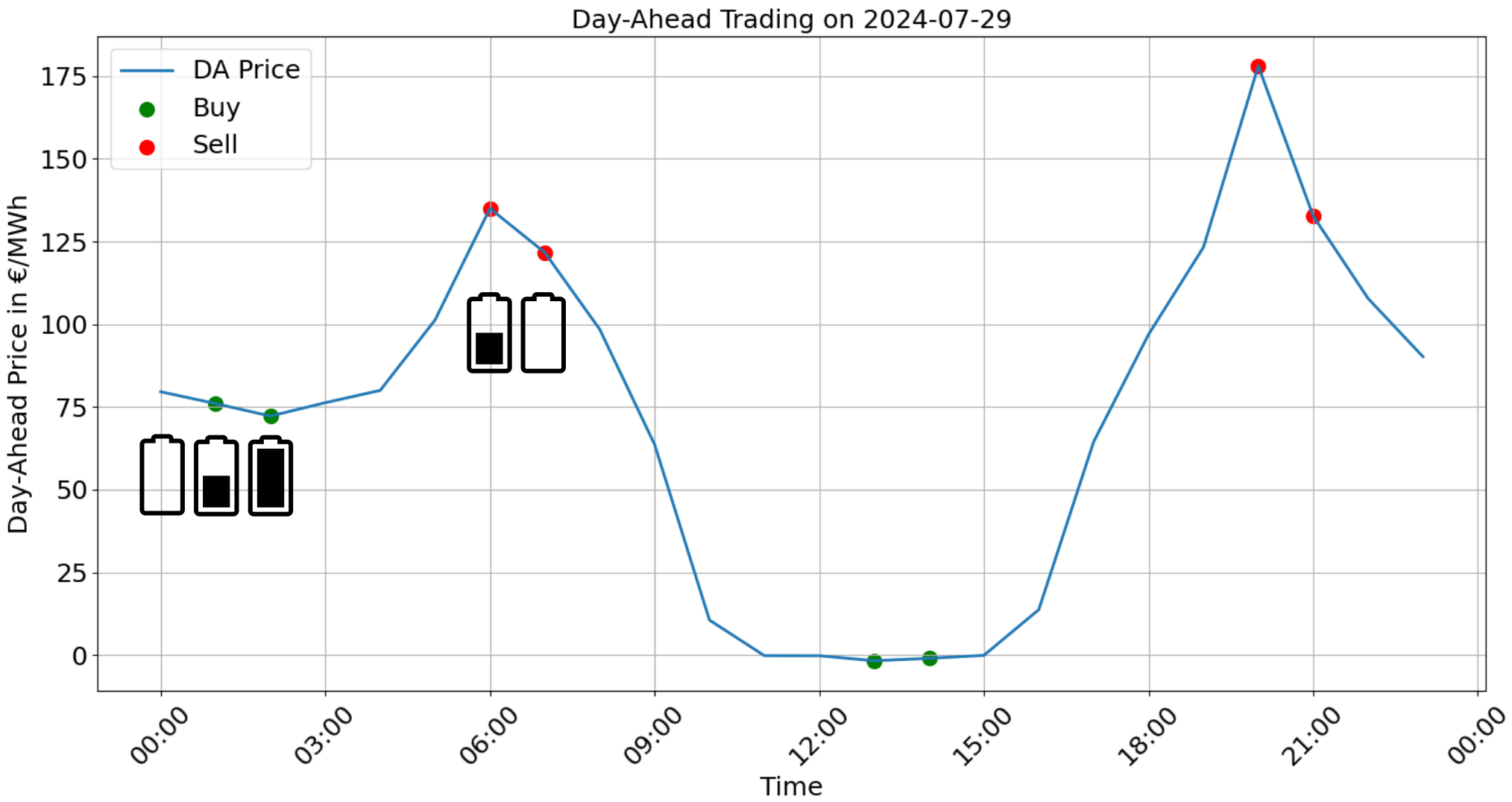

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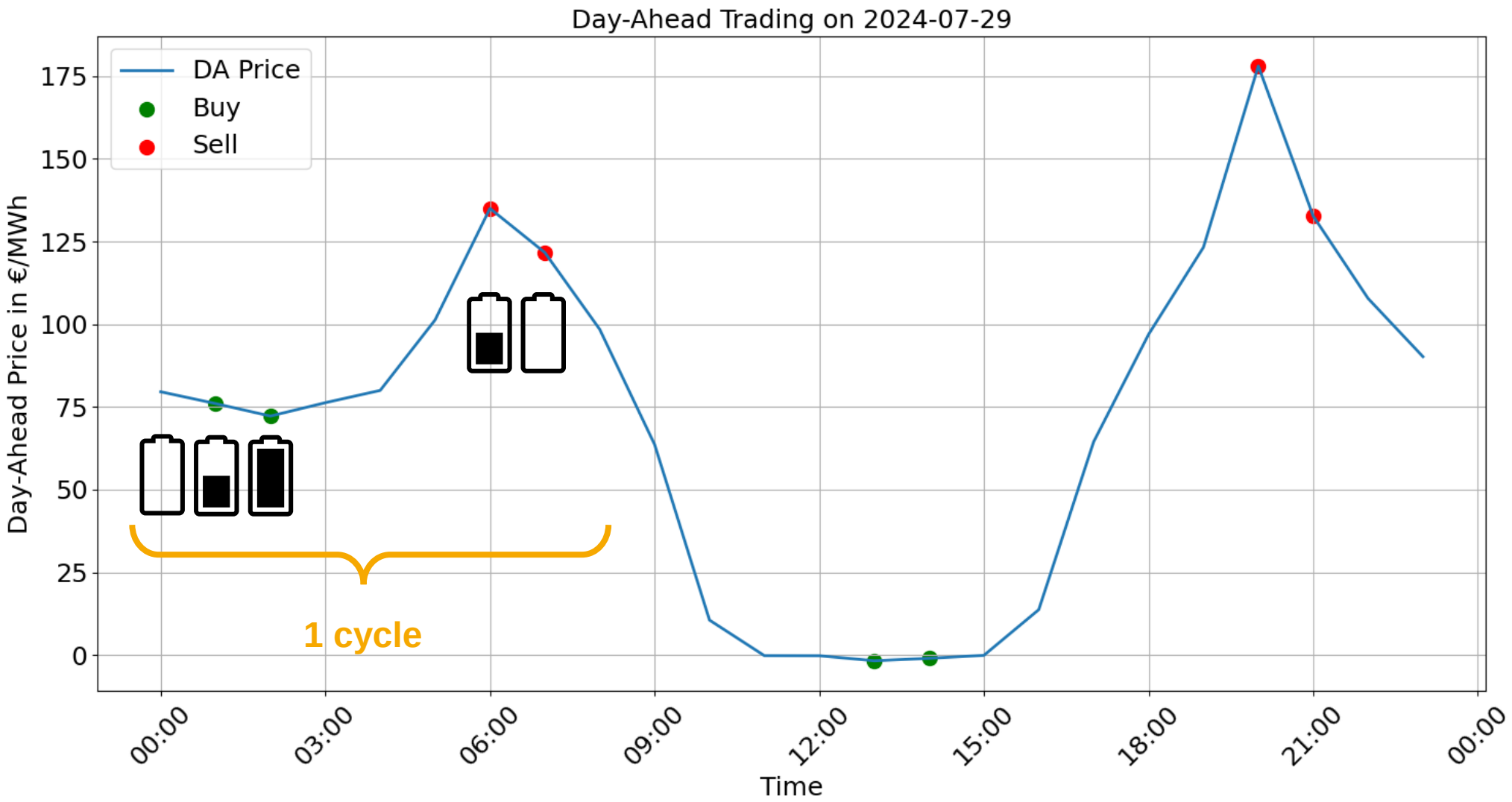

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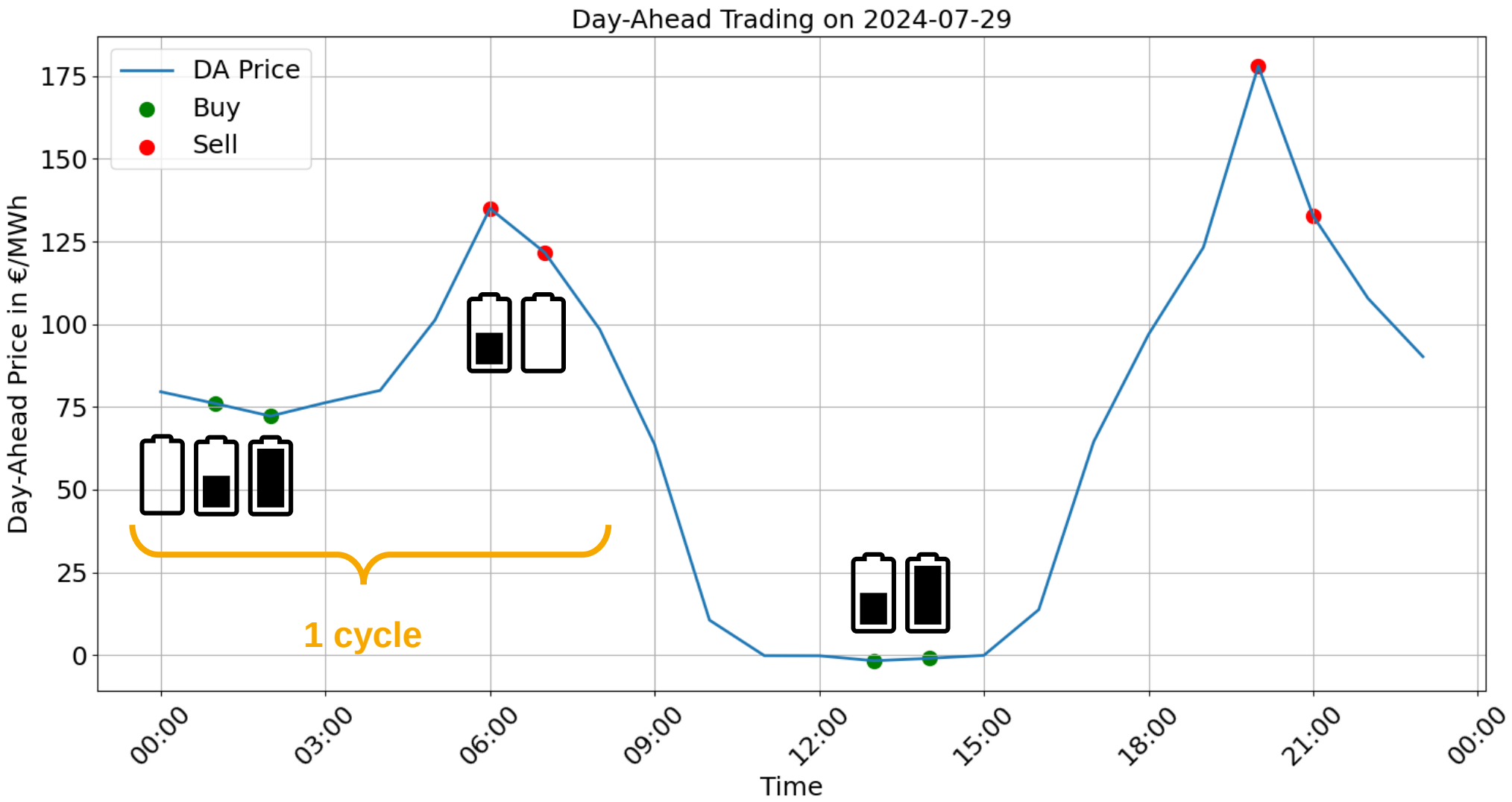

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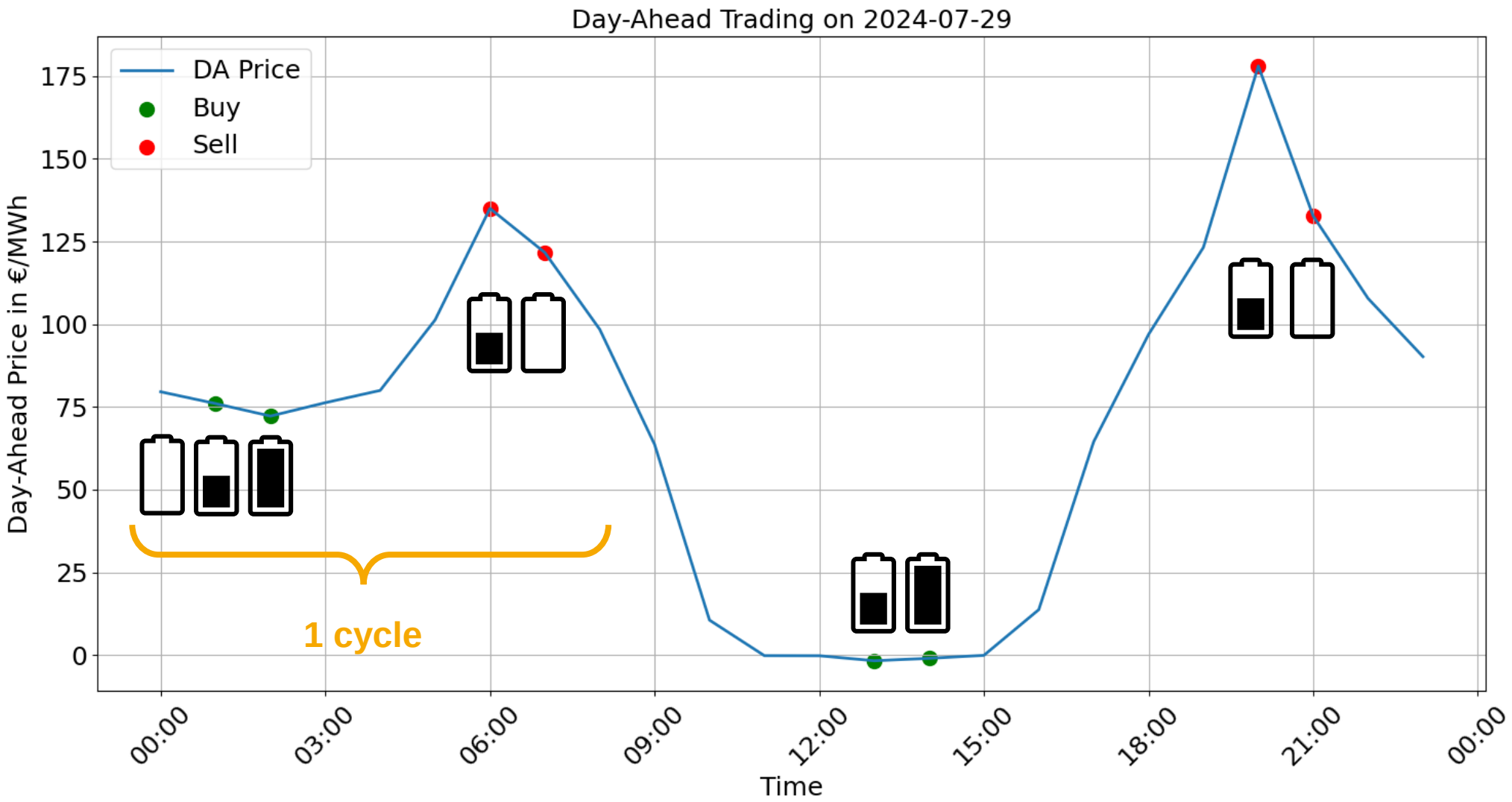

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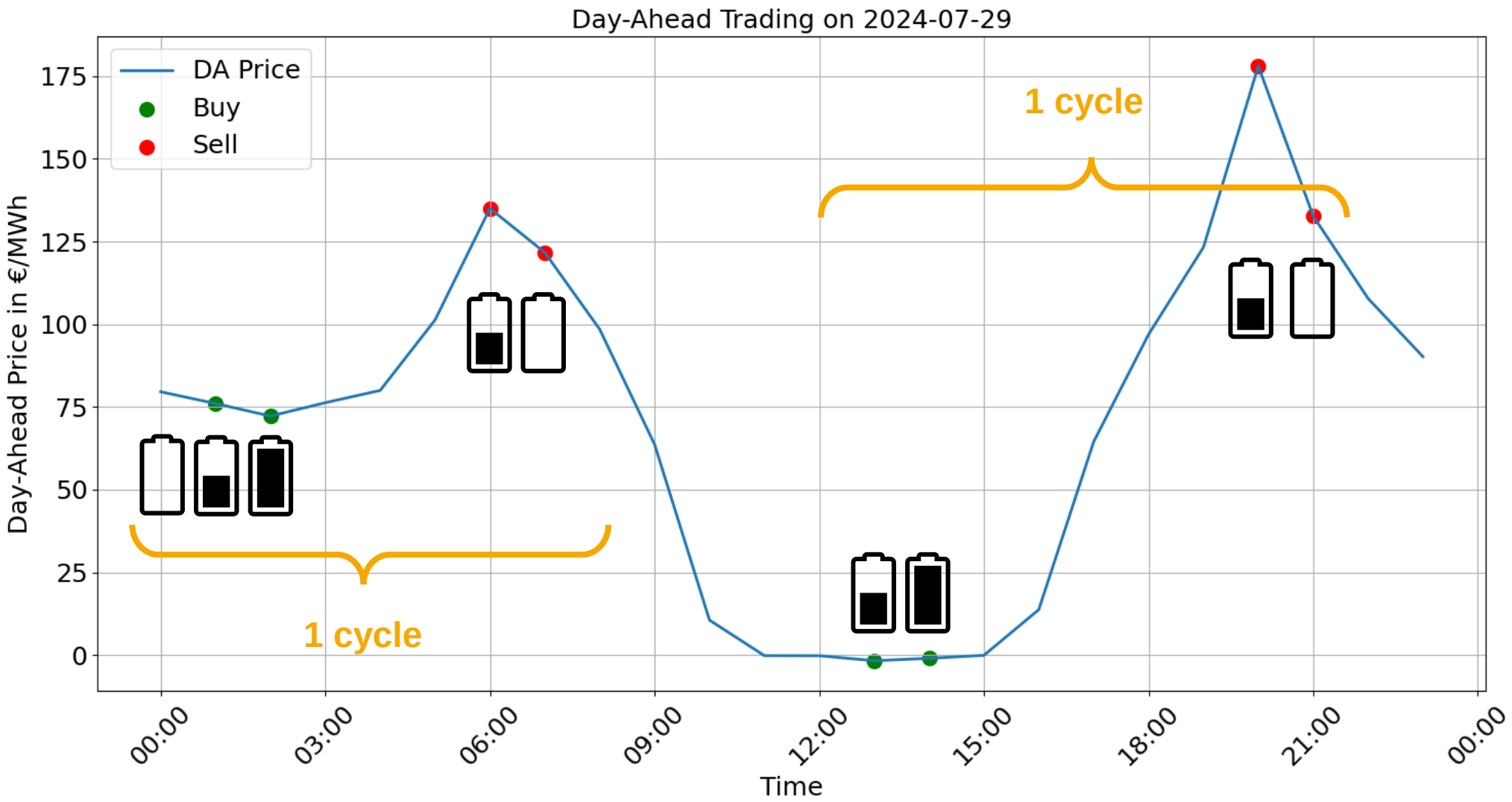

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PHASE 1: FCR/aFRR market approach (stand alone, greenfield)

FCR

- Assumption: continuous participation with market clearing price (pay-as-cleared)
- Symmetrical bidding required

$$P_{marketable} = \frac{P_{max}}{1.25}$$

$$Revenue = P_{marketable} * p_{clearing}$$

Max. provision: 15 minutes
PQ-Cond.: recharge reserve of 25%

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$$Revenue = P_{marketable} * p_{clearing}$$

Max. provision: 15 minutes
PQ-Cond.: recharge reserve of 25%

aFRR

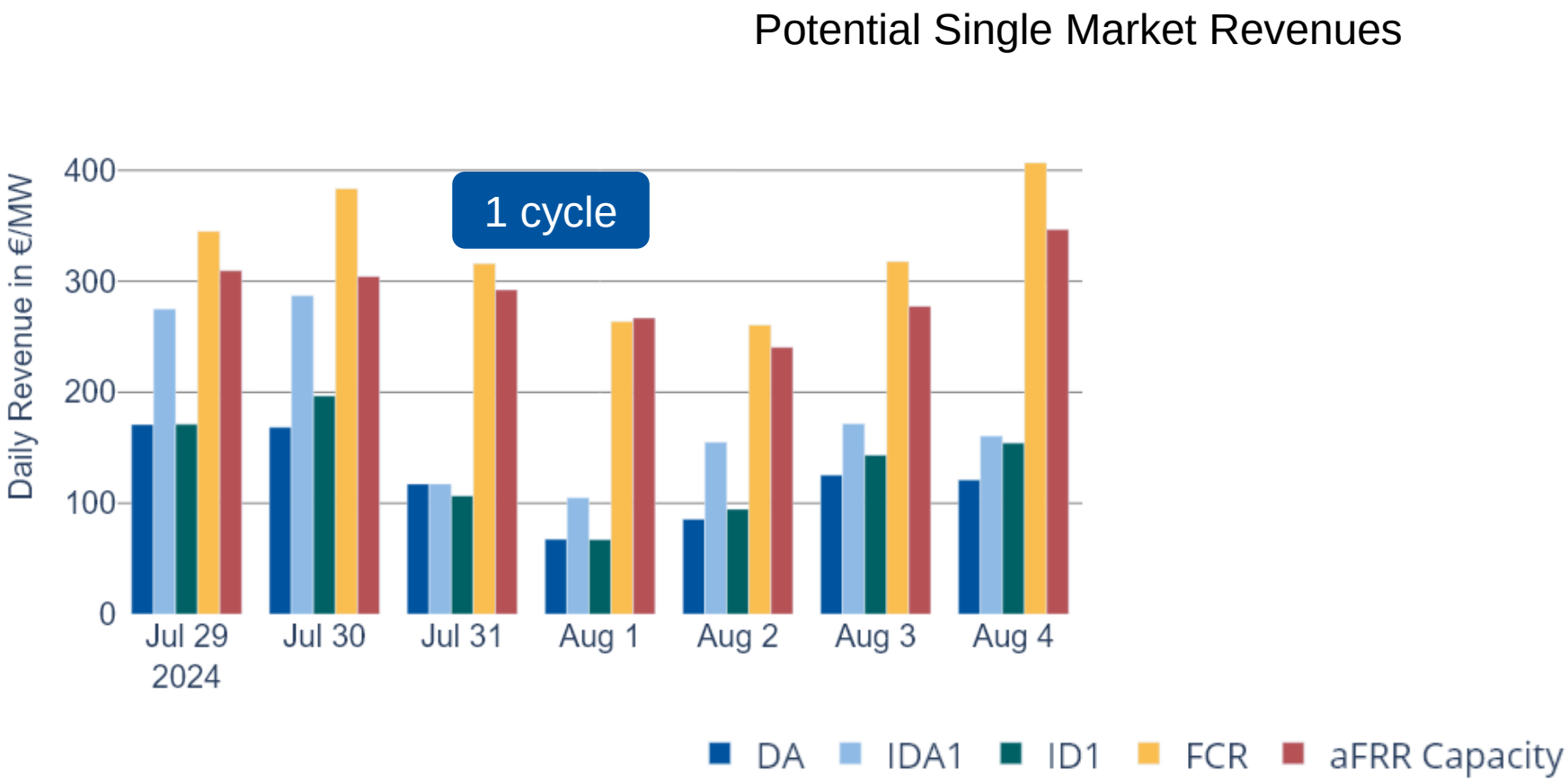
- Assumption: continuous participation with average bidding price (pay-as-bid)
- Capacity market only / symmetrical bidding

$$P_{marketable} = \frac{E_{max}}{2h}$$

$$Revenue = P_{marketable} * p_{average,bid}$$

Max. provision: 1 hour
50% bidding on positive/negative aFRR

PHASE 1: results for single market (SM) revenues (1 hour system)



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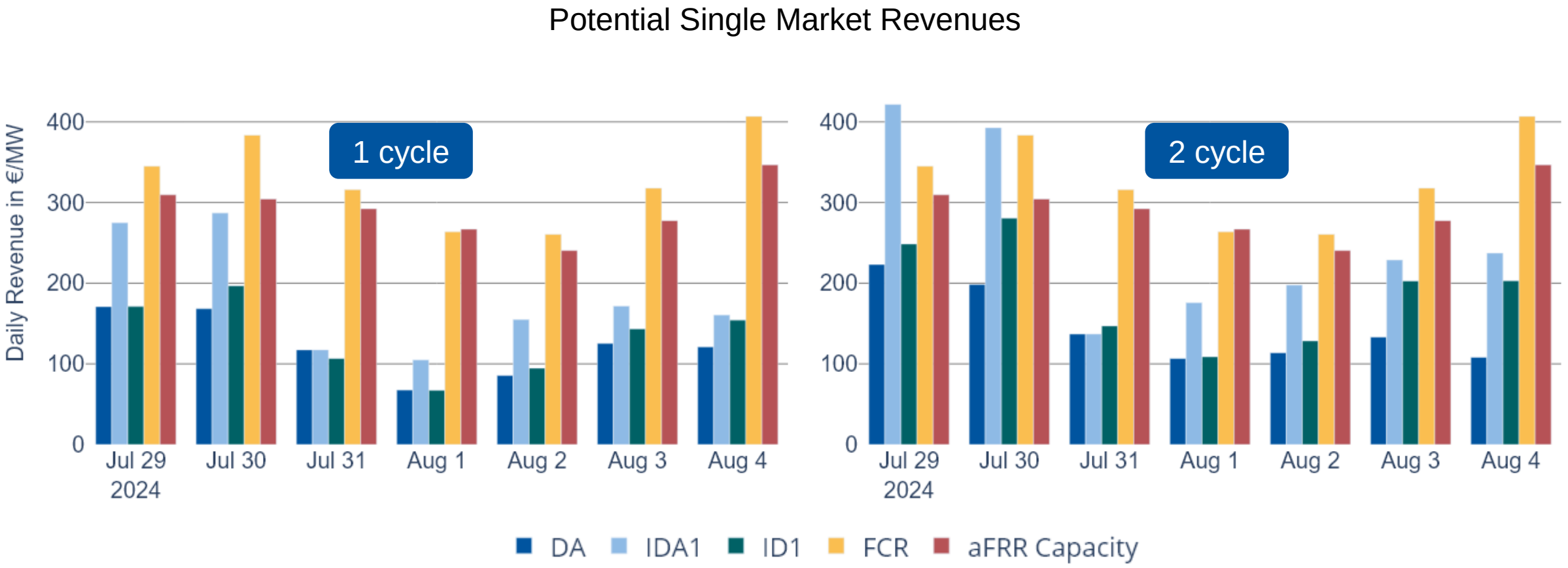

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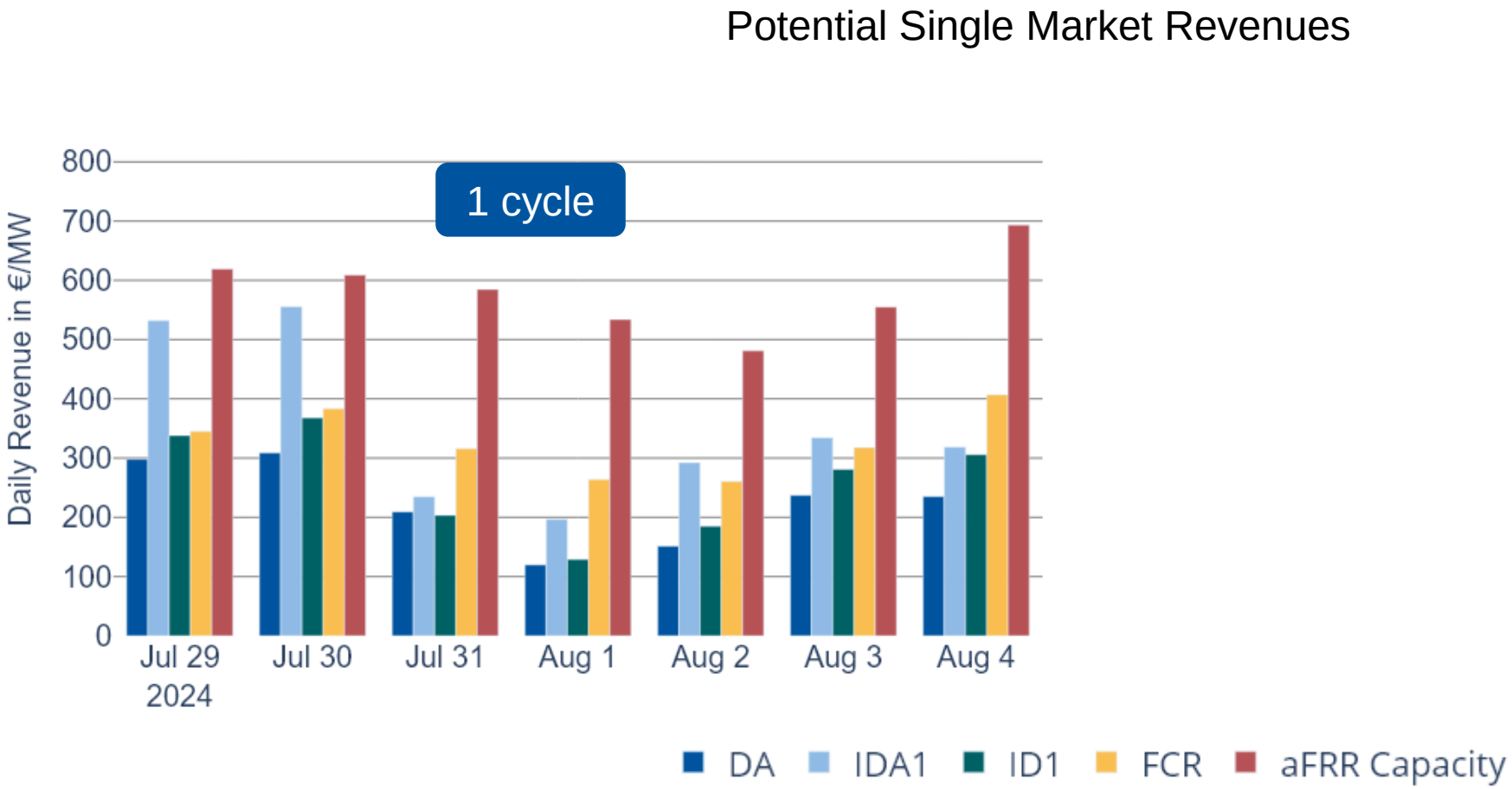

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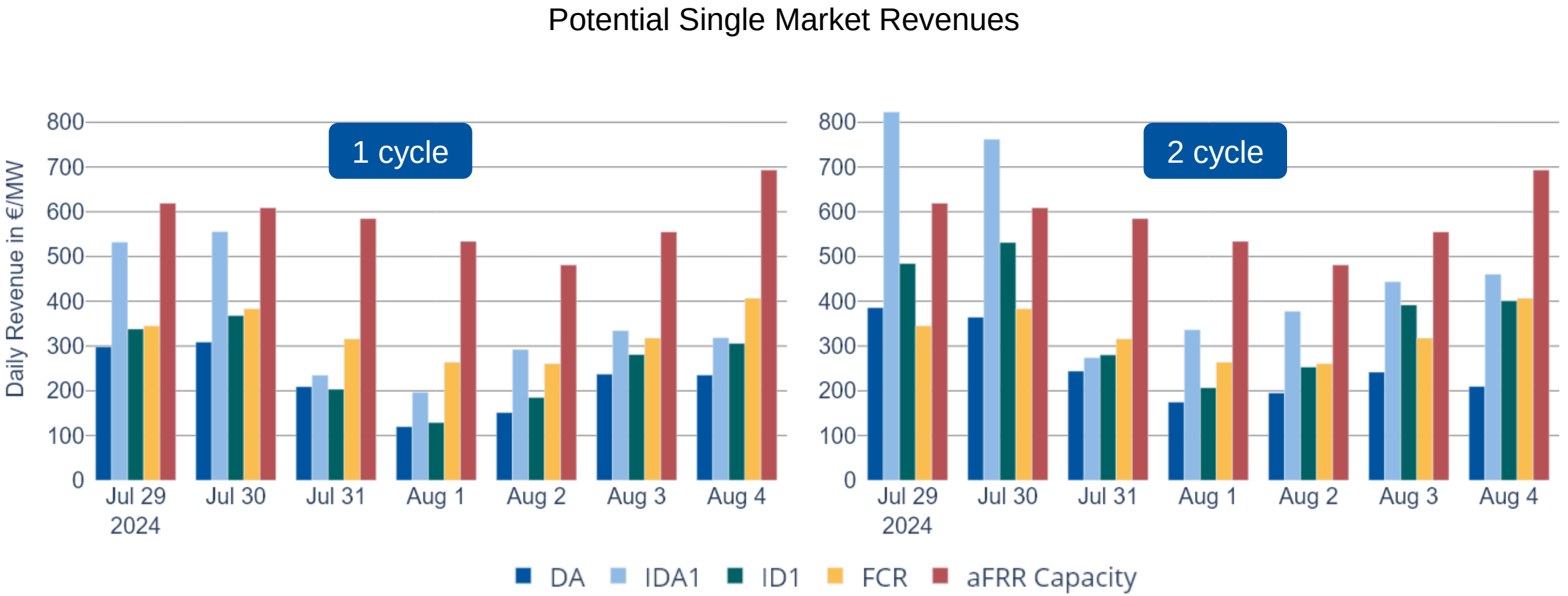

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Index development: 4-phase approach

PHASE 1

Aim: single markets revenue potentials

Single markets
No financial trades
aFRR/FCR: capacity only

PHASE 1.5

Combining markets
simple weighting

PHASE 2

Aim: combined market revenue potentials

Combining markets
Financial trades
aFRR: capacity only

Block approach
Physical boundaries
Fixed parameters

PHASE 3

Aim: sophisticated cross-market index

Cross-market
Financial trades
aFRR: capacity/energy

Variable time steps
Physical boundaries
Variable parameters

PHASE 4

Aim: validating index with real asset

Validation of index
Real asset
M5BAT or other

Loss factors
Operational constraints

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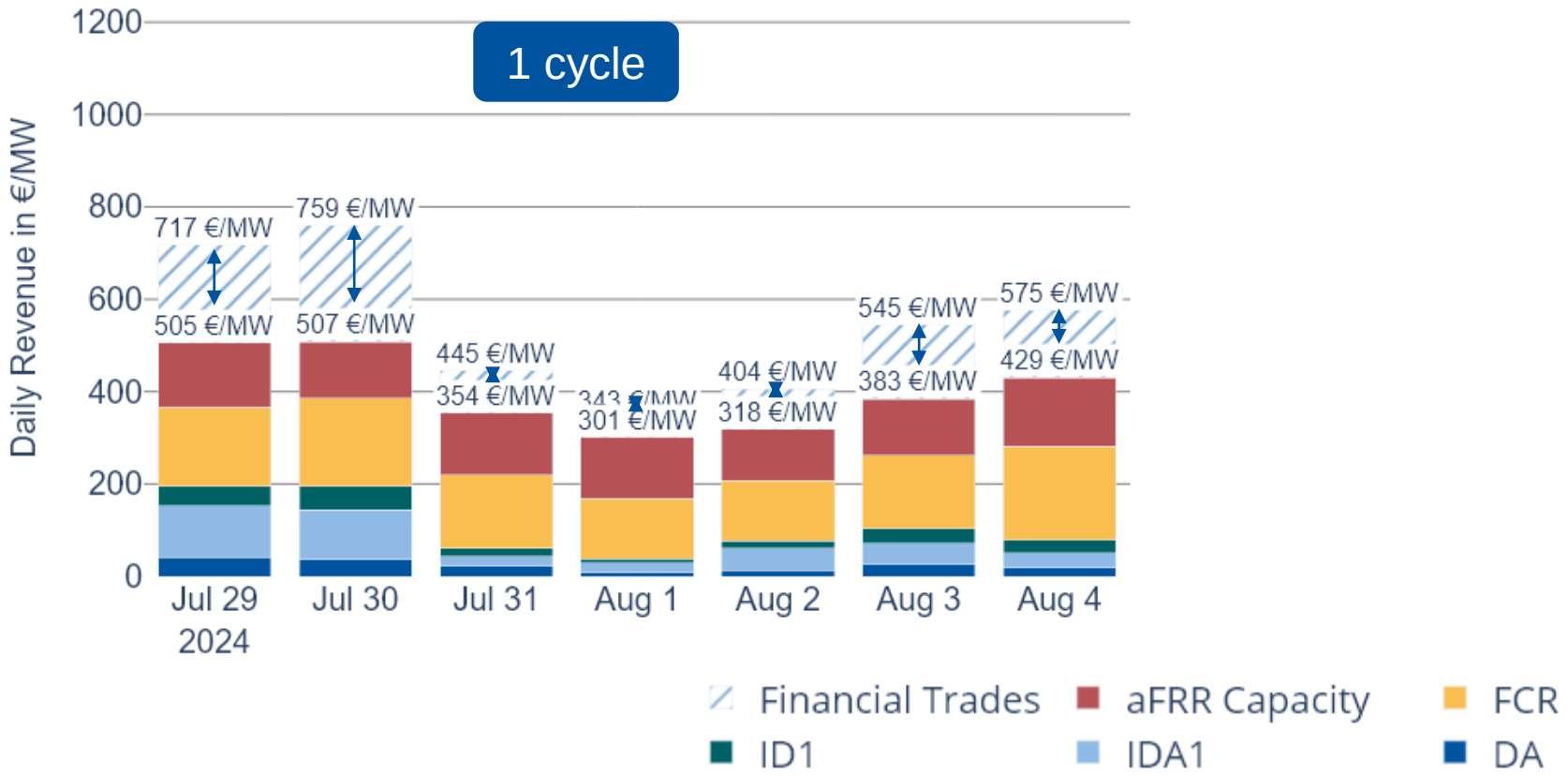
PHASE 1.5 - results for cross-market (CM) revenues (1 hour system)

Assumption: factor for financial trades = 5 times of asset backed financial trades on IDC (ID1)

Potential Cross-Market Revenues

$$FCR_{share,CM} = \frac{FCR_{rev,SM}{}^{2}}{0.5 * max(rev_{SM})}$$



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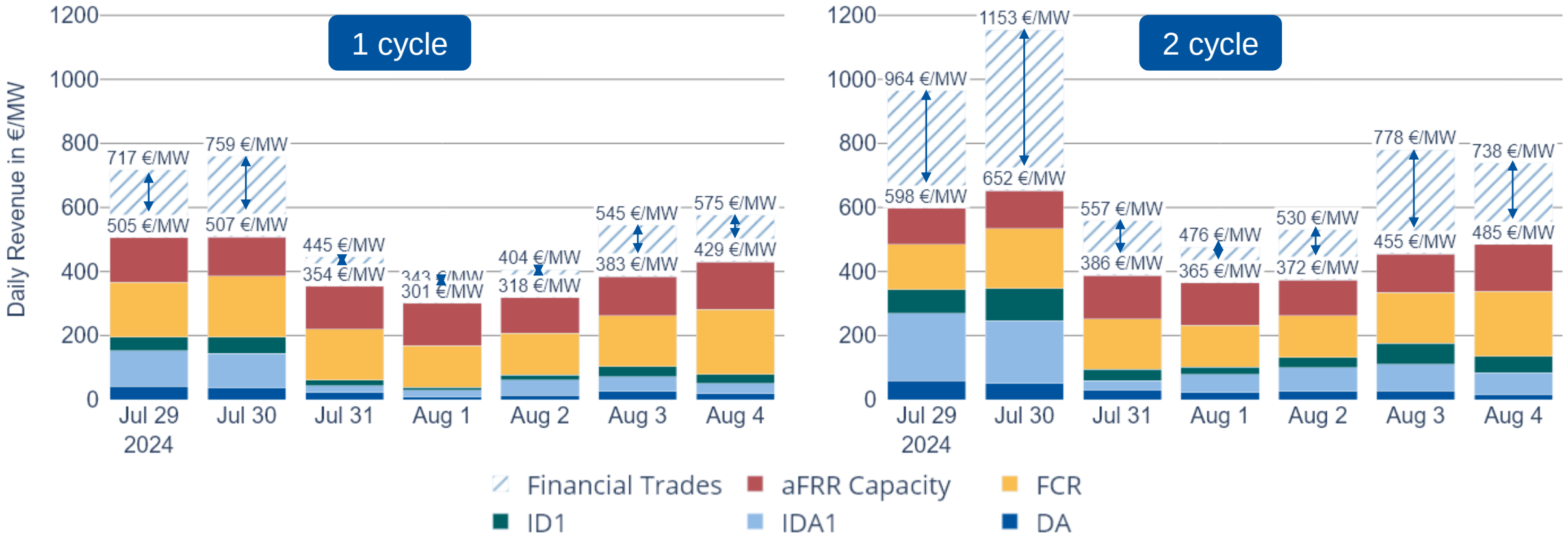

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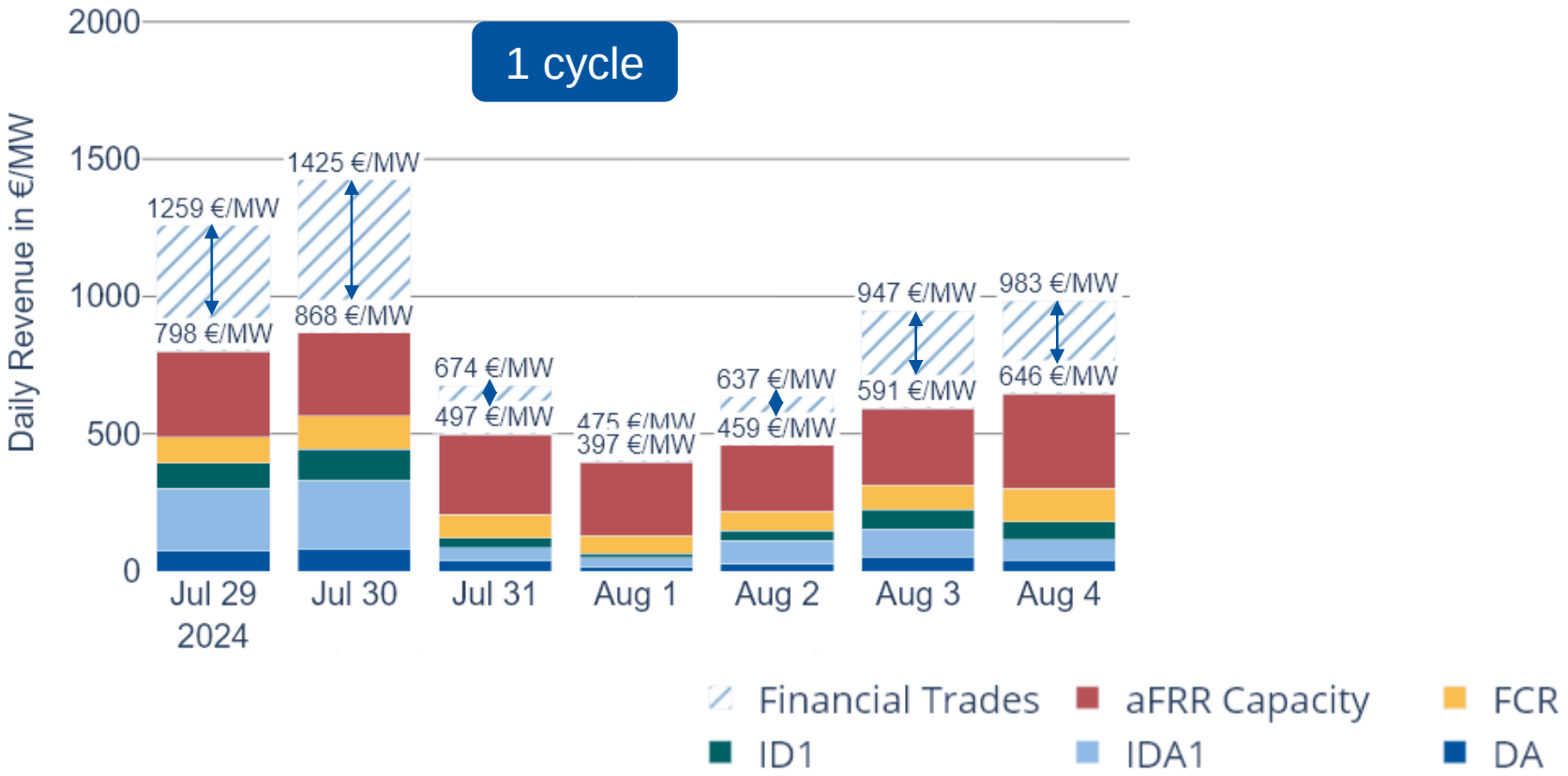

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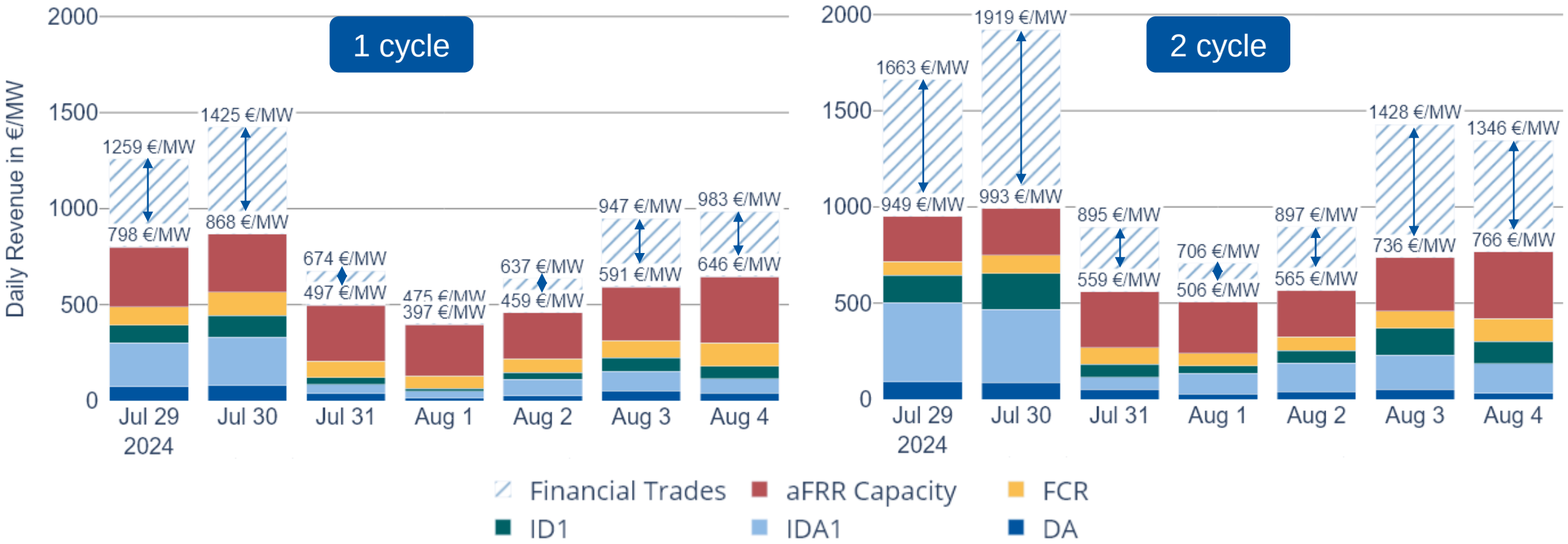

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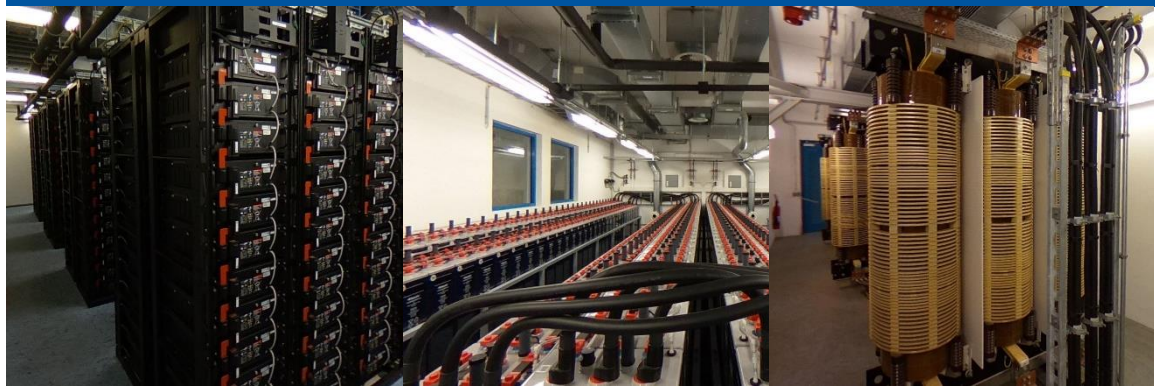
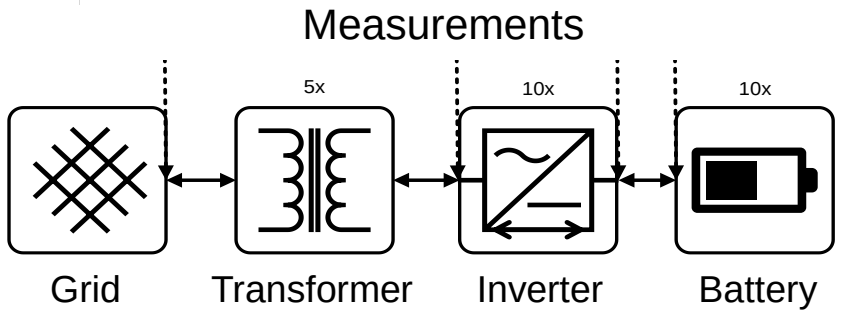
PHASE 4: validating battery index on a real asset

Live Monitoring: https://m5bat.isea.rwth-aachen.de/





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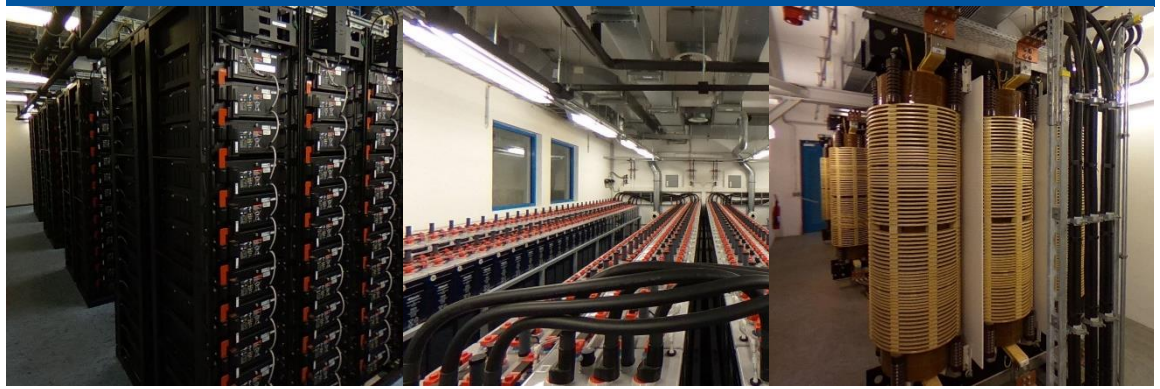
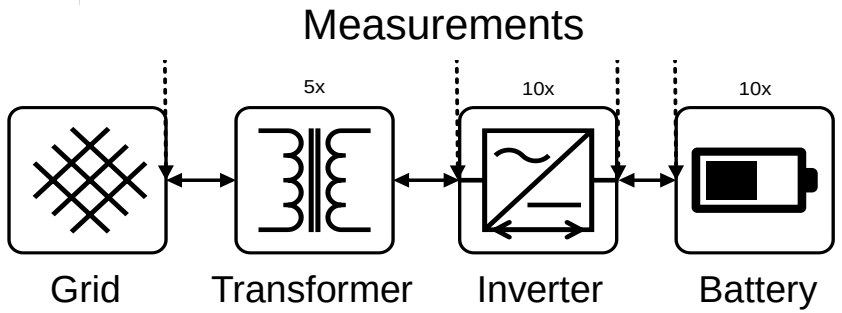


- Calculating appropriate loss factors and evaluating operational constraints



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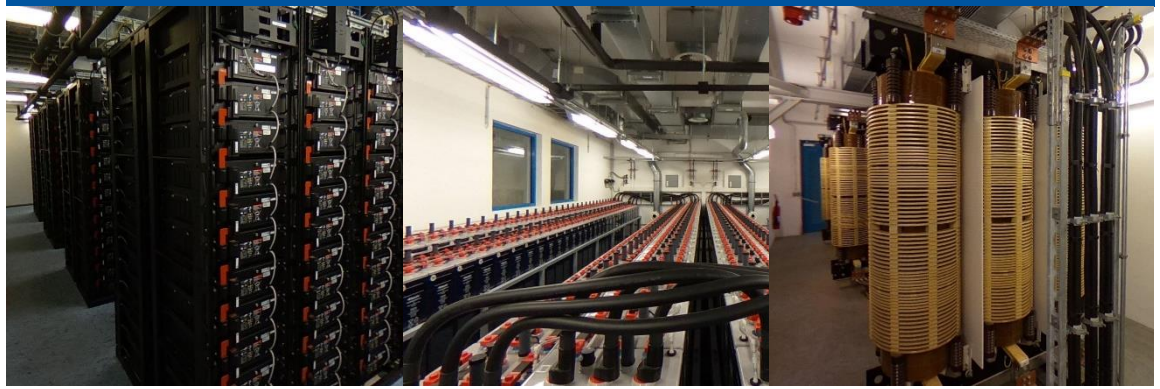

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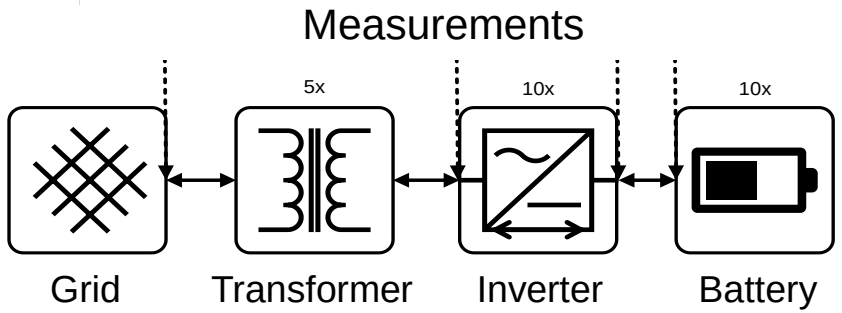
- Idea: using research battery storage system M5BAT or another real assets for validation



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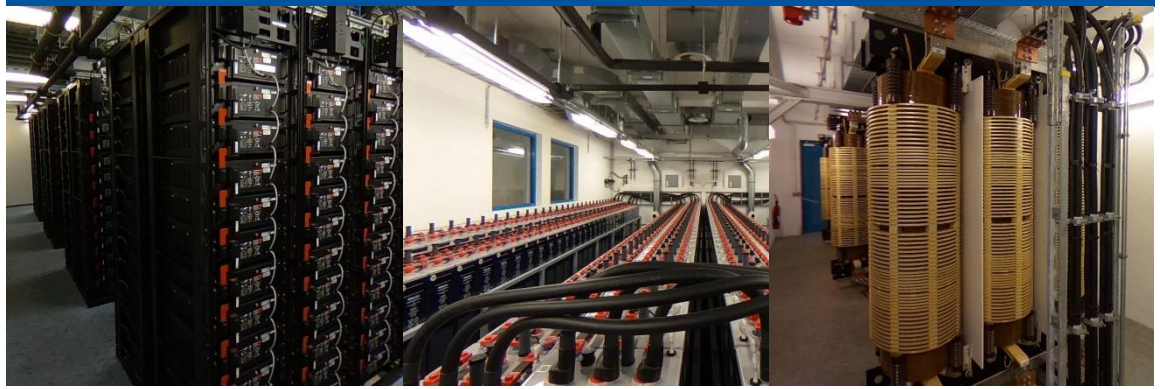
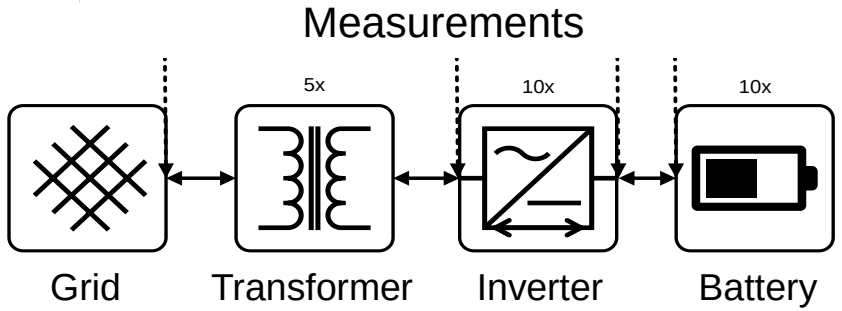


- Calculating appropriate loss factors and evaluating operational constraints
- Idea: using research battery storage system M5BAT or another real assets for validation
- Advantages M5BAT:
  - MW testing under real market conditions
  - High-resolution measurements
  - Different battery technologies
  - Operational since 2017
  - Experienced research staff



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Publication: regular updates on battery-charts.de

→ www.battery-charts.de

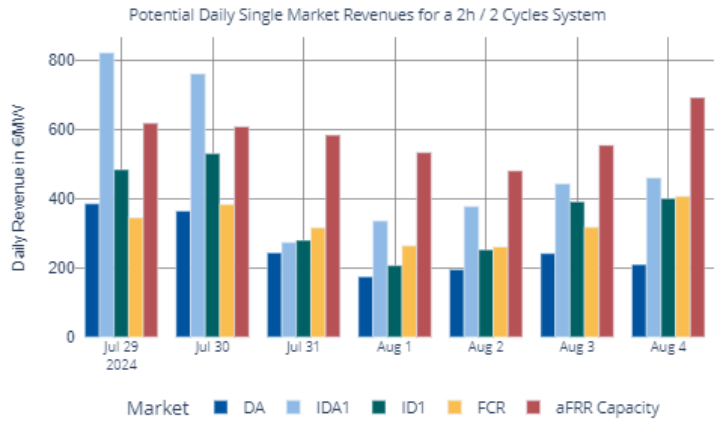
Battery Revenue Index (Beta-Version)

Together with Enspired GmbH, ISEA is developing an index for the German battery market that is intended to transparently map the revenue potential for large-scale storage systems with regard to grid services. The index is currently under development and will be finished in the coming months (Date: 09.2024).

The index was developed by Jonas Brucksch and Jonas van Ouwerkerk. The index takes into account the spot markets (day-ahead auction, intraday auction, intraday continuous trading) as well as the balancing markets (FCR, aFRR). The index is intended to help increase market transparency and provide a basis for investors, project developers and traders to better evaluate potential revenues. The index is intended to create comparability, but not to reflect the actual maximum achievable proceeds. Rather, the index should be designed so simply that it is comprehensible and can be calculated in Excel, for example.

The cross-market index value is calculated from the potentials of the individual markets in the lower figure, when combining all considerded markets. The revenue potential is included in the index in proportion to thalf of the maxium potential of all single markets. A possible target range is estimated for financial trades (maximum factor of 5 compared to intraday continuous asset-backed trades).

Abbreviations:
DA: Day-ahead market
IDA1: Intraday auction (calculation with averaged indices one hour prior to delivery)
ID1: Intraday continuous trading (calculation with averaged index one hour before delivery)
FCR: Primary control reserve (Frequency Containment Reserve)
aFRR: Secondary control reserve (Automatic Frequency Restoration Reserve)



Outlook: what is to come?

GetEnspired

enspired

September-December 2024:
Regular updates of the index (beta) are released on *battery-charts.de*

End of 2024
Sophisticated cross-market index (alpha) is available online

Beginning of 2025
Validation on a real asset / full publication of methodology

- Main challenges
  - Keeping it simple
  - Considering financial trades
  - Adding aFRR energy market

Thank you
for your attention

More market data:
www.battery-charts.de
www.mobility-charts.de

Contact

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We thank

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Developing a battery index for Germany

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10-Sep-24

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E.ON Energy Research Center | RWTH AACHEN UNIVERSITY

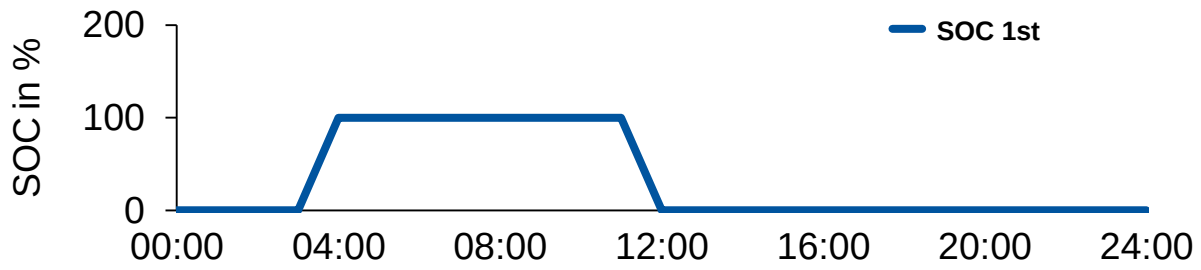
Center for Ageing, Reliability and Lifetime Prediction of Electrochemical and Power Electronic Systems (CARL)

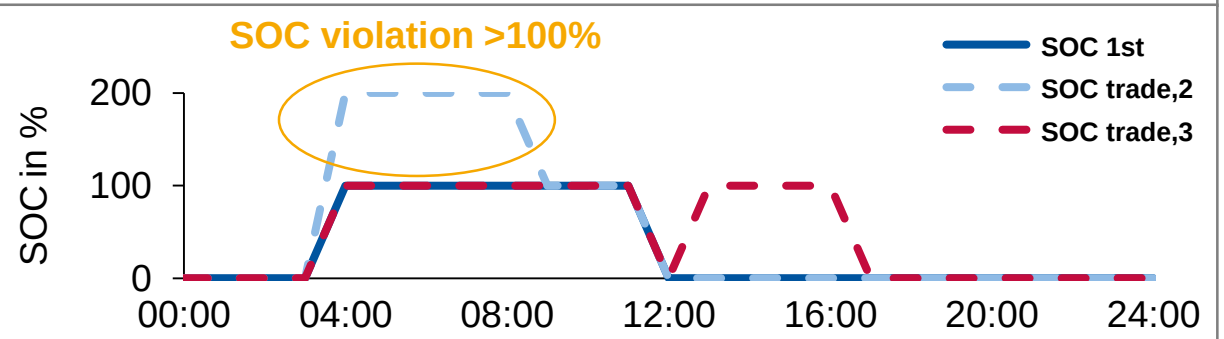
CARL Center for Ageing, Reliability and Lifetime Prediction of Electrochemical and Power Electronic Systems | iSEA Power Electronics and Electrical Drives | RWTH AACHEN UNIVERSITY

BACKUP: PHASE 1: Day-ahead market approach

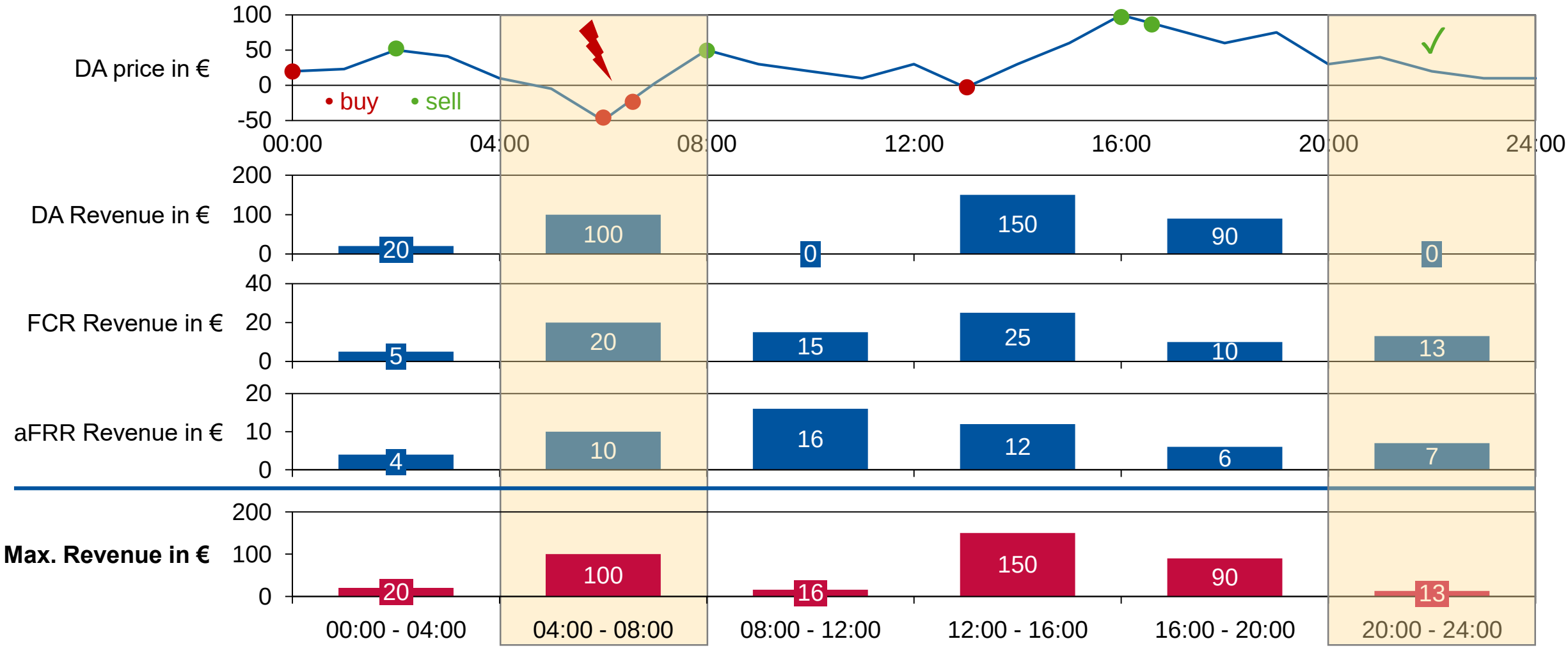
- Procedure (for 1h System, 2 cycle):
  - STEP 1: Calculating ordered list of trade pairs within one day (576 combinations)
  - STEP 2: Selecting trade with highest spread as 1st trade
  - STEP 3: Calculating generic state-of-charge (SOC) profile with 1st trade (SOC_{1st})
  - STEP 4: 2nd trade: calculating $SOC_{trade,x}$ when adding another remaining trade (for all combinations), power lower than P_{max}
  - STEP 5: Selecting trade with highest spread (>20 €/MWh), where $SOC_{trade,x}$ is valid (0-100%)
  - STEP 6: Continue same procedure for 3rd, 4th, 5th, 6th 7th and 8th trade
- Further assumptions:
  - Round-trip efficiency: 100%, SOC_{usable}: 10-90%

Trade	Buy (h)	Sell (h)	Spread (€/MW)	Take?
1	**4**	**12**	**100**	**yes: 1st**
2	4	8	50	no
3	13	16	30	yes: 2nd
...	...	...	...	...
576	23	24	-50	no



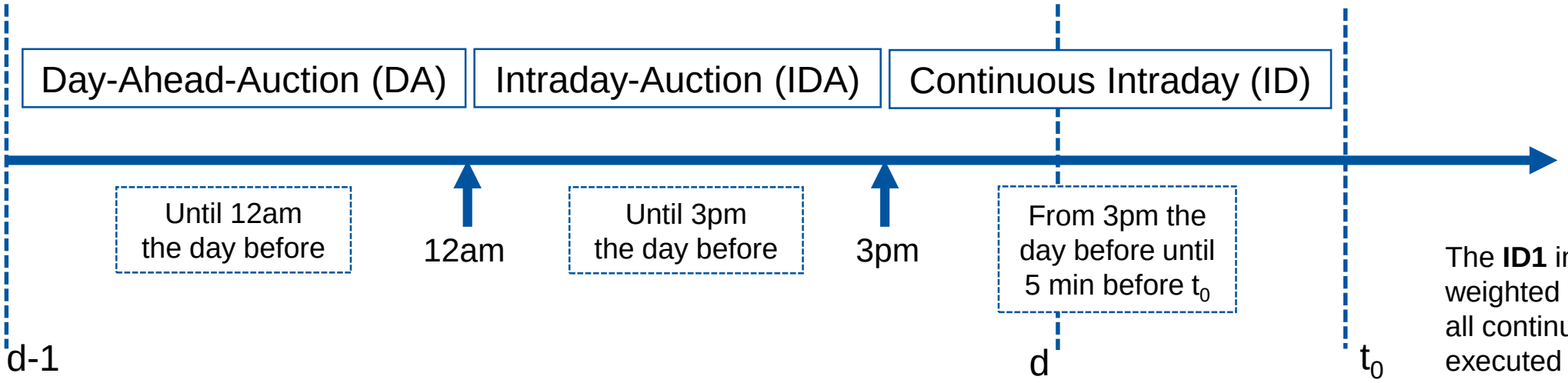


BACKUP: PHASE 2: Cross-market combination – block approach



For each 4h-block the market with the highest revenue is selected. Condition FCR/aFRR: no trades on DA

BACKUP: Market basics – trading on Day-Ahead und Intraday markets



The **ID1** index is the weighted average price of all continuous trades executed within the last trading hour

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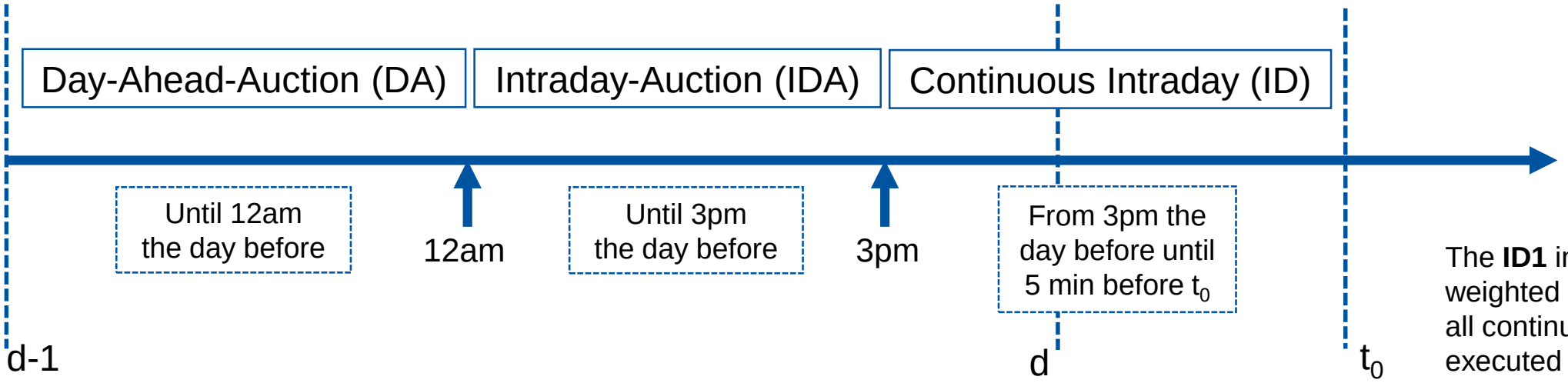

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Day-Ahead-Market	Intraday-Markets
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hourly products	hourly / quarterly products
pay-as-cleared	pay-as-bid

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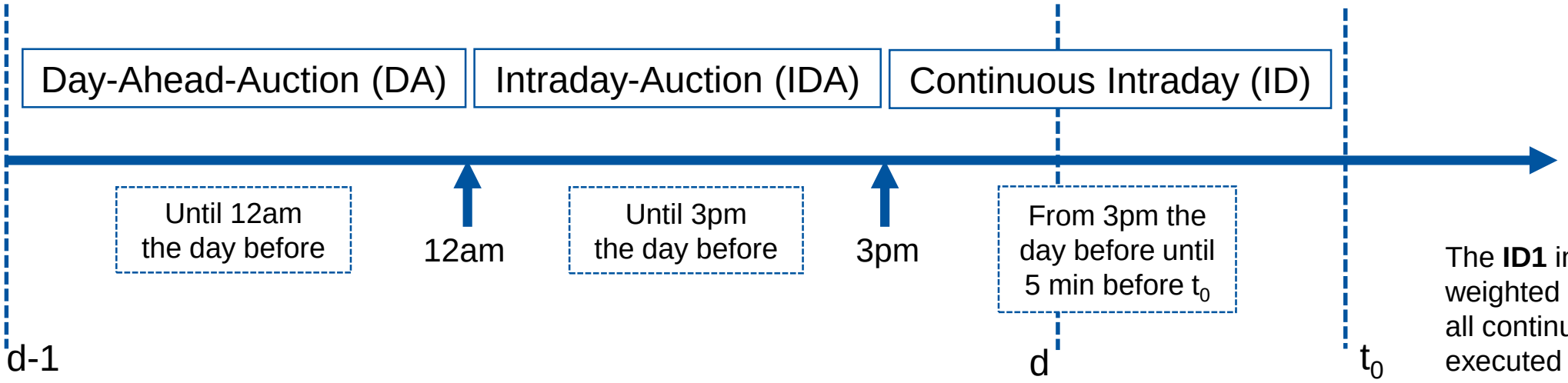

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ID-indexes

- ID-Full
- ID1
- ID3

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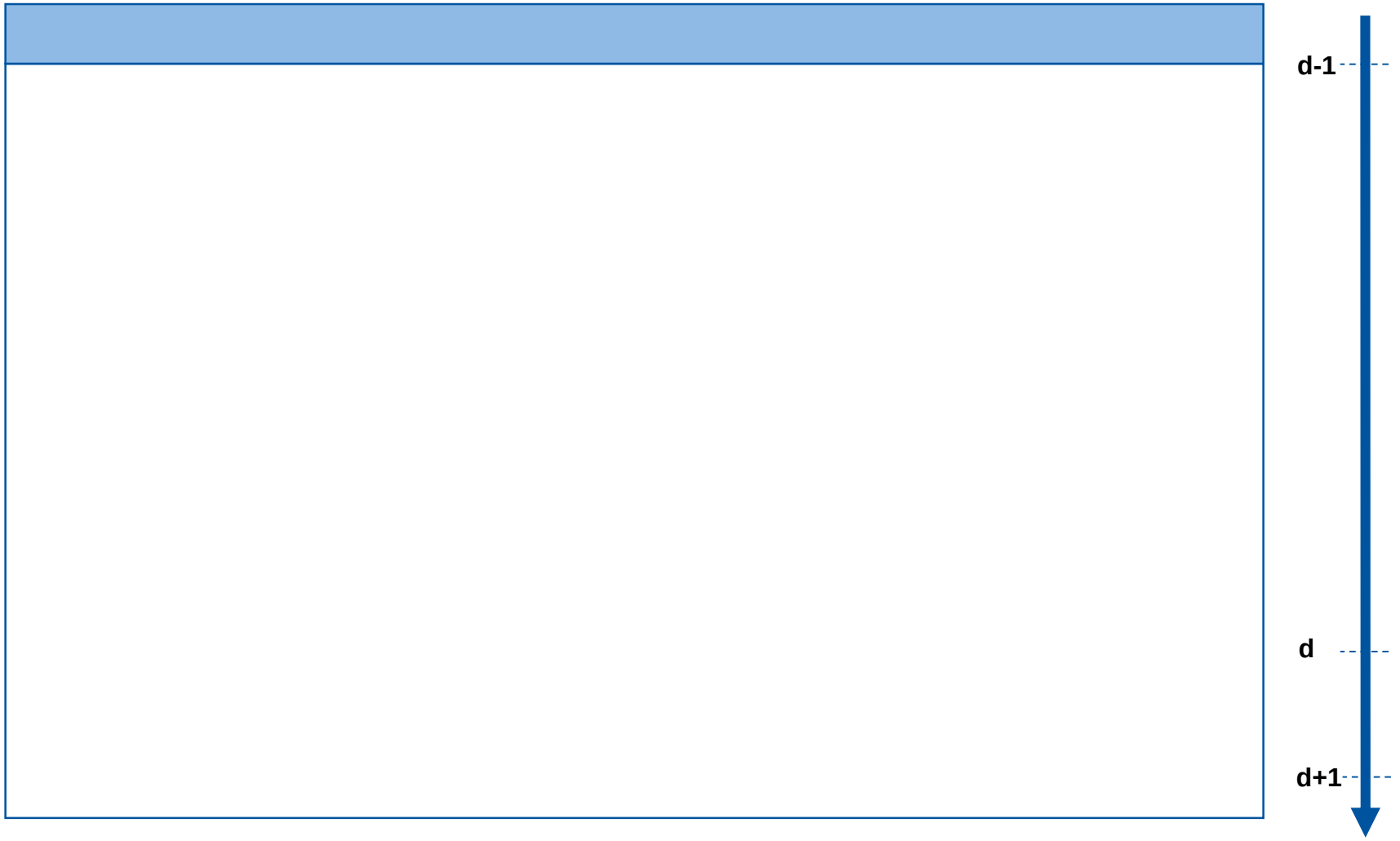

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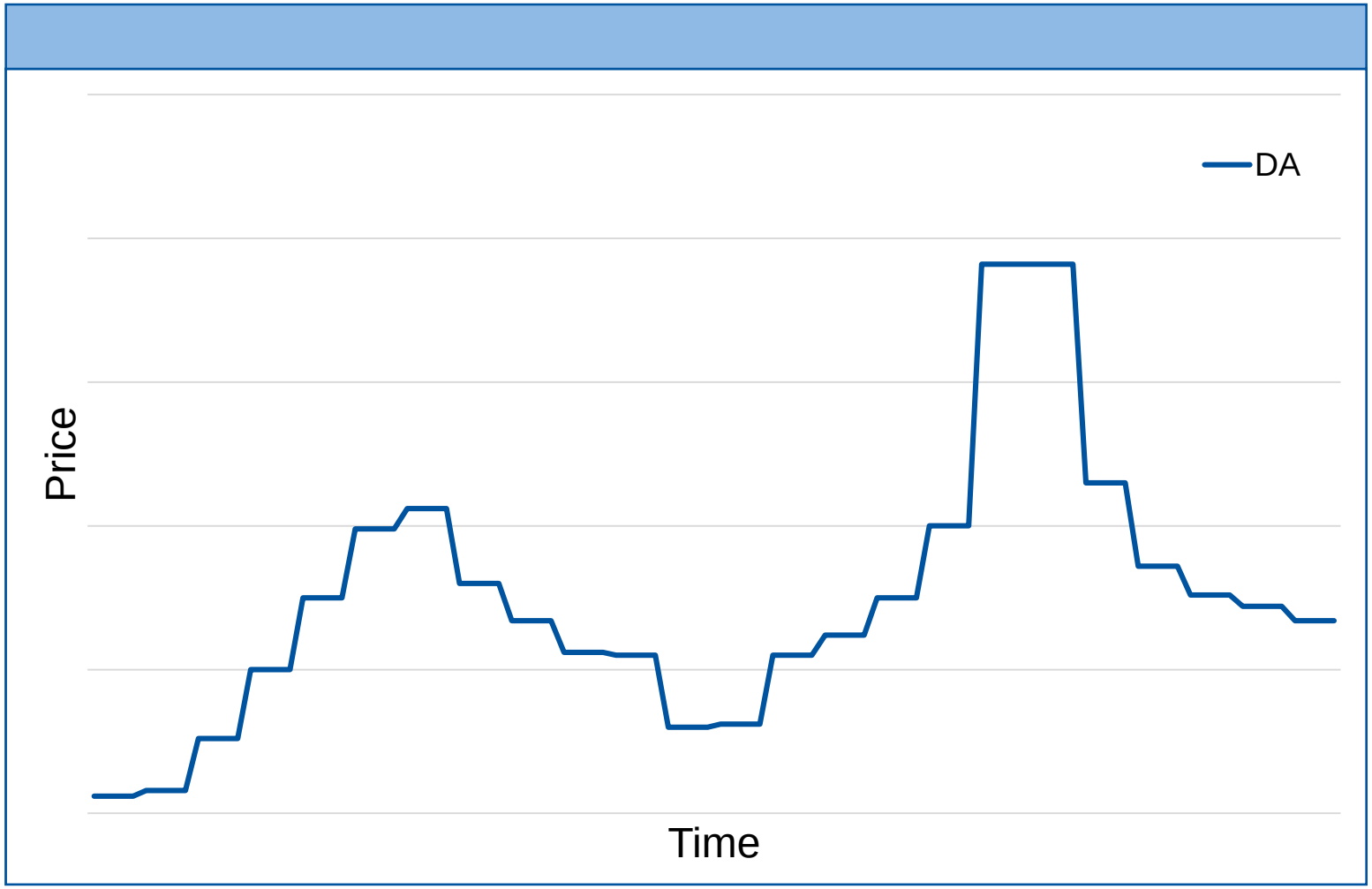

Bidding on day-ahead

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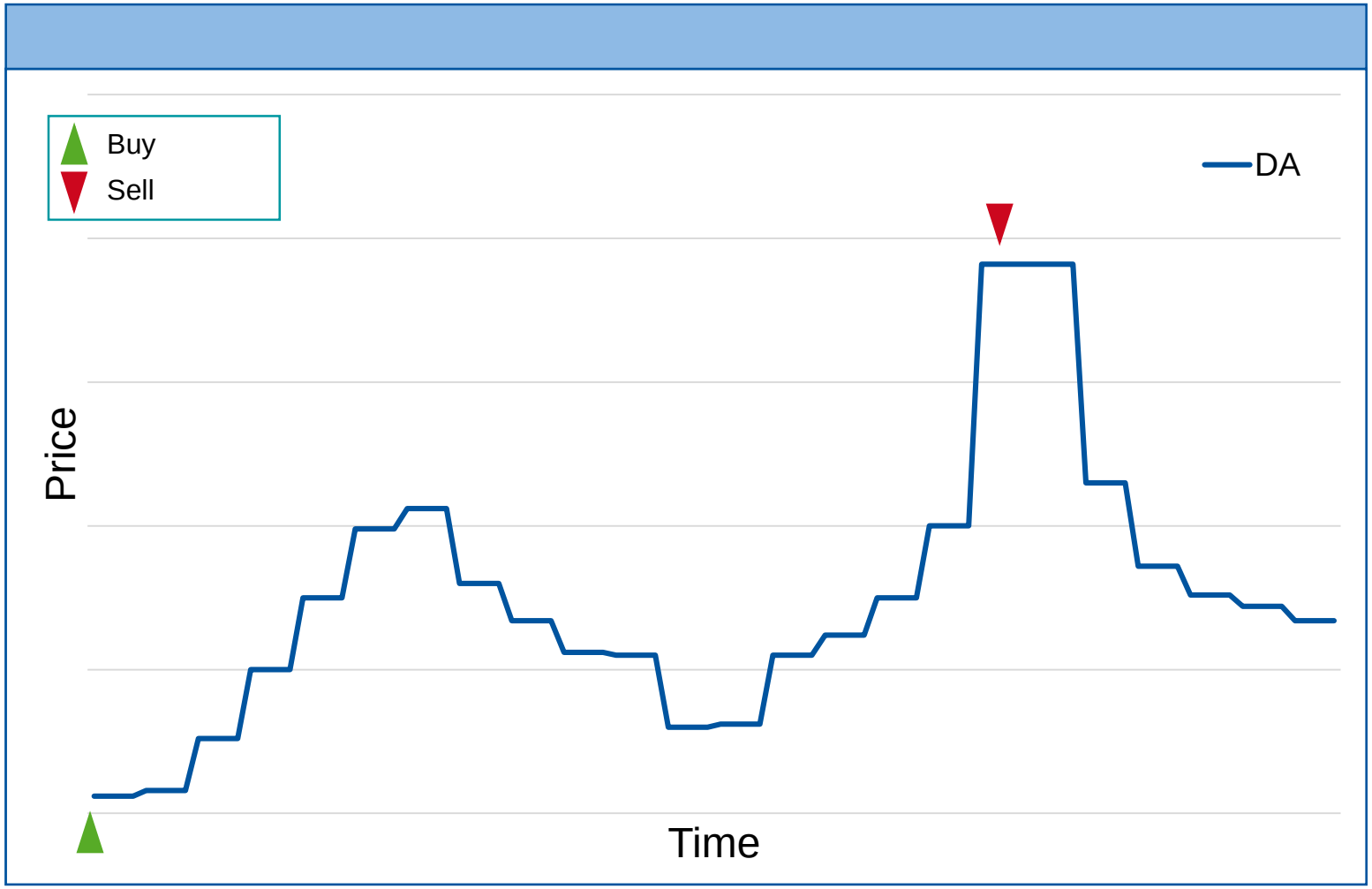

Bidding on day-ahead

DA bids

Intramarket Spread DA

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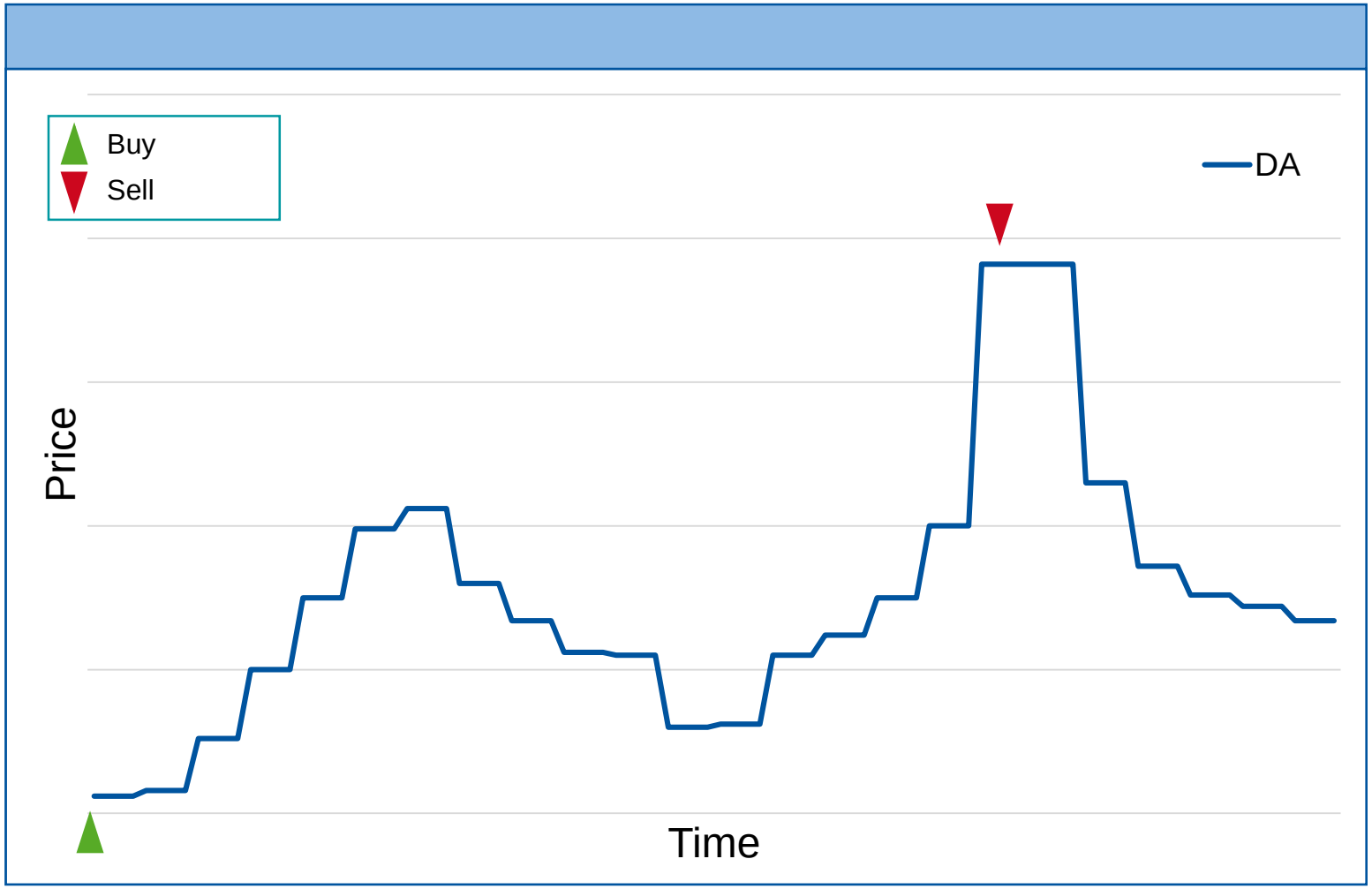
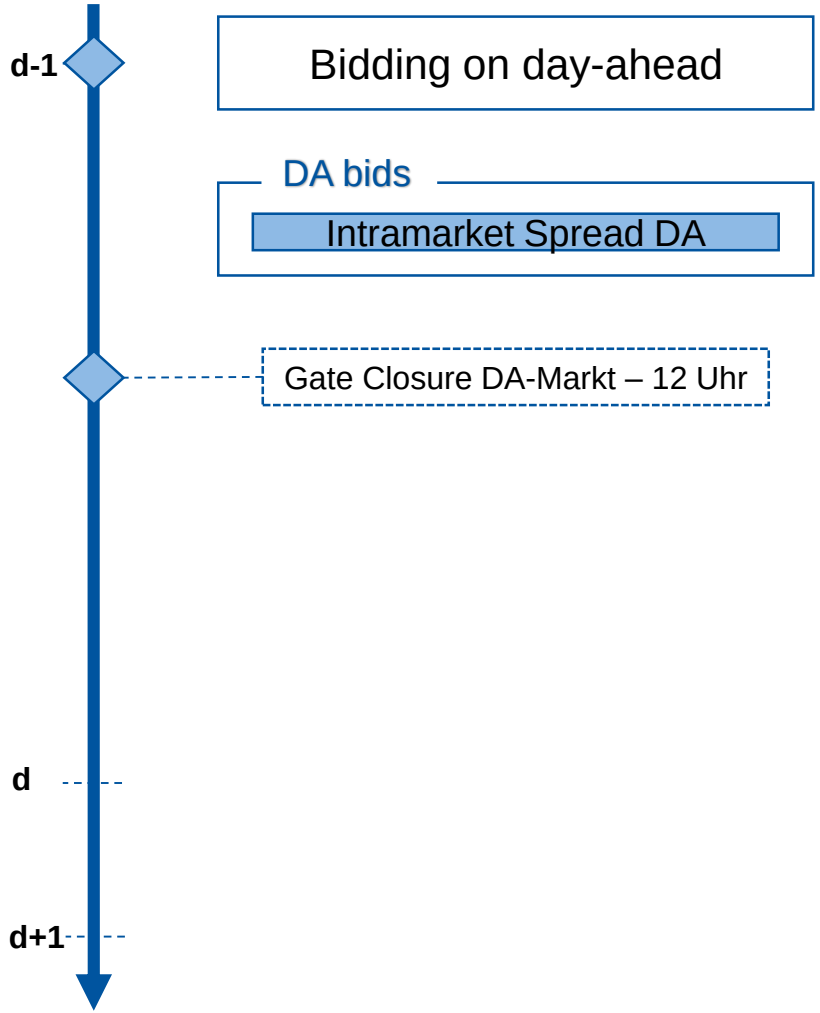
BACKUP: Market basics – trading on Day-Ahead und Intraday markets





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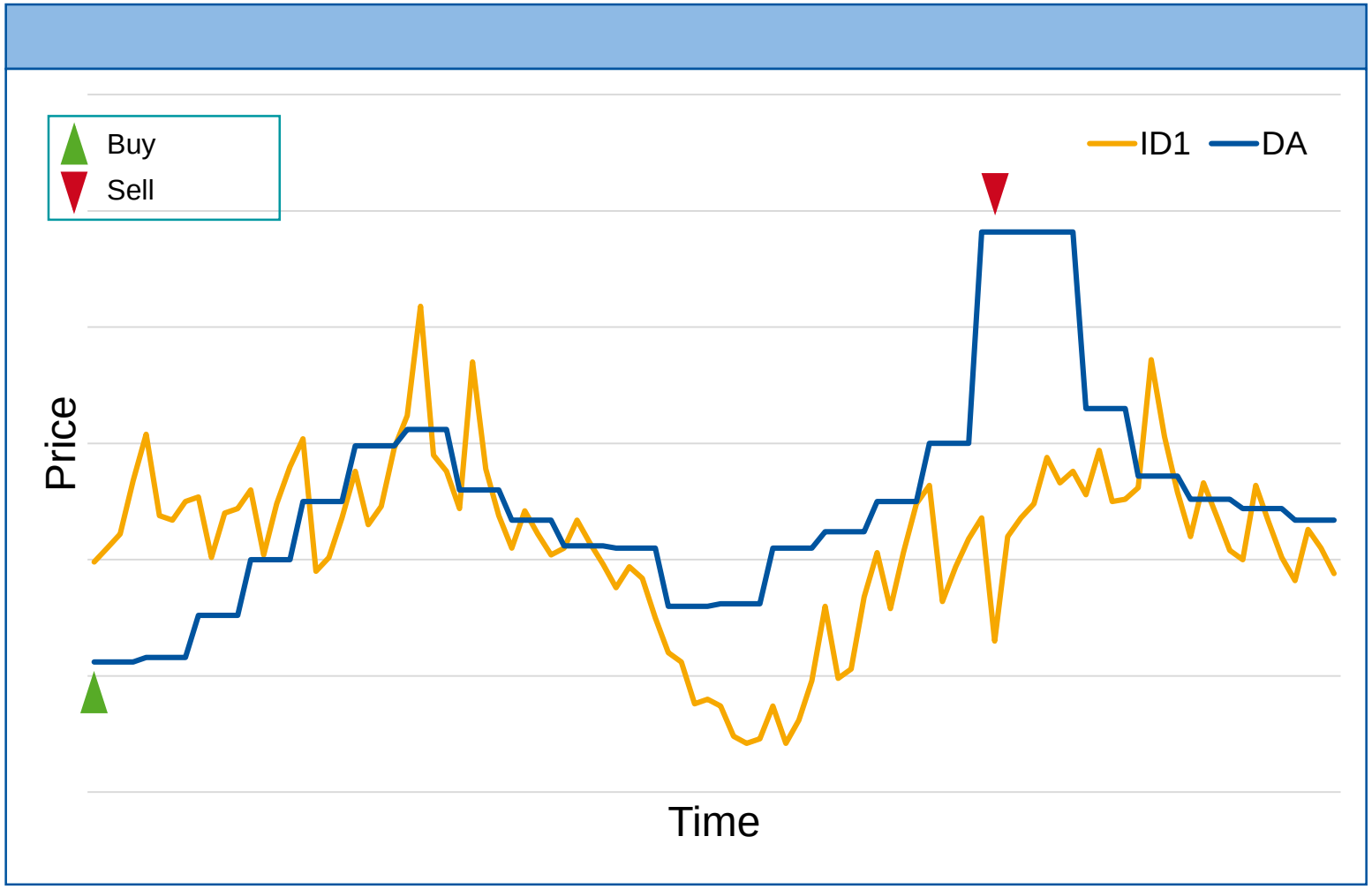

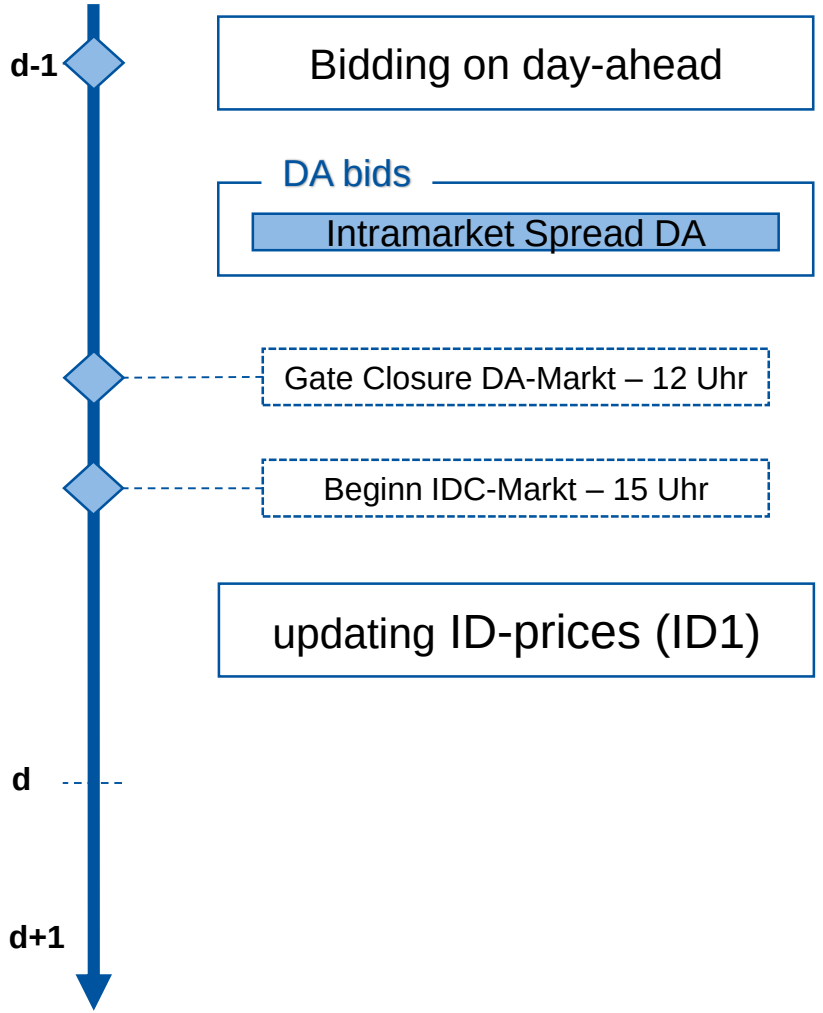

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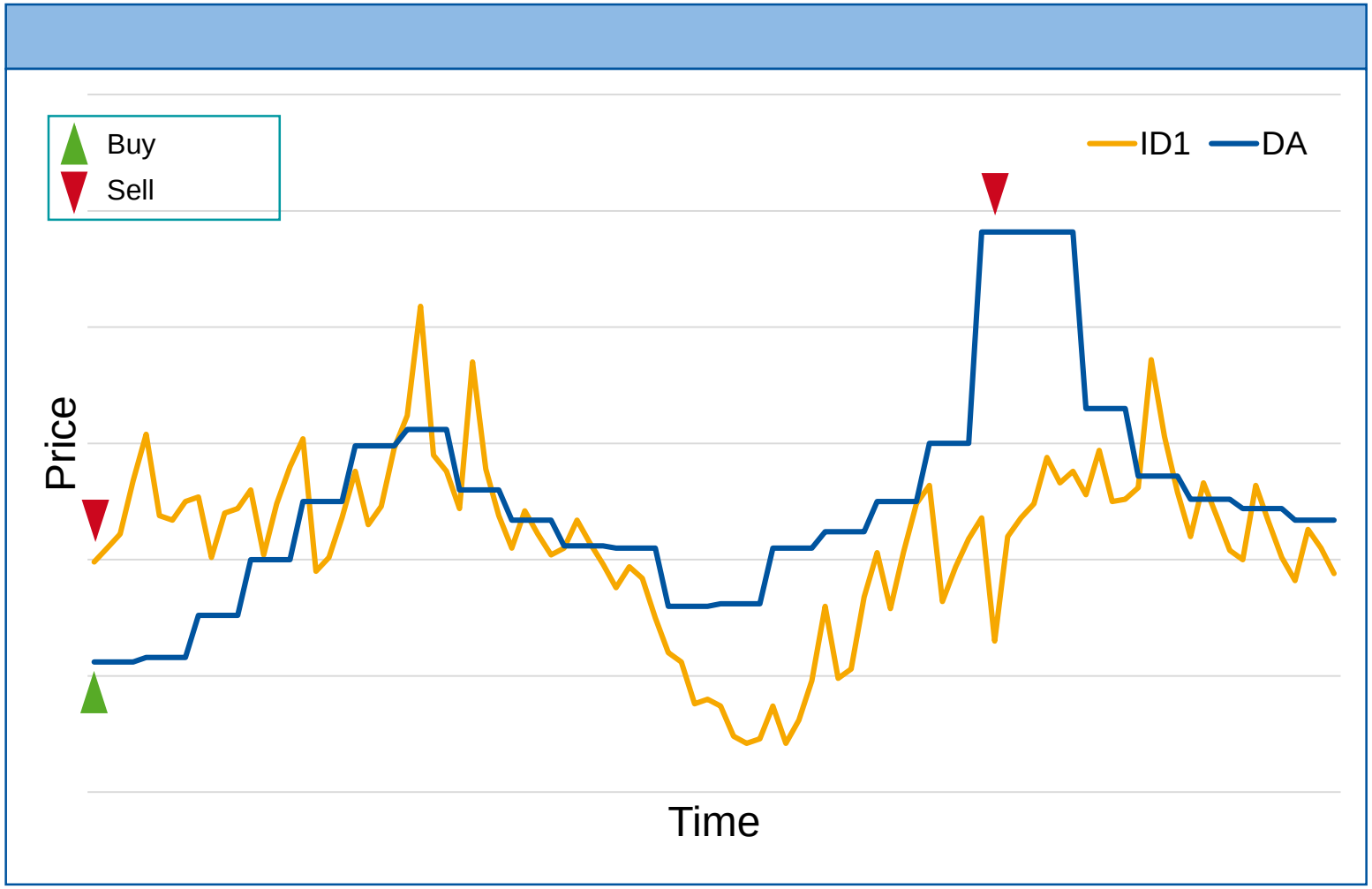

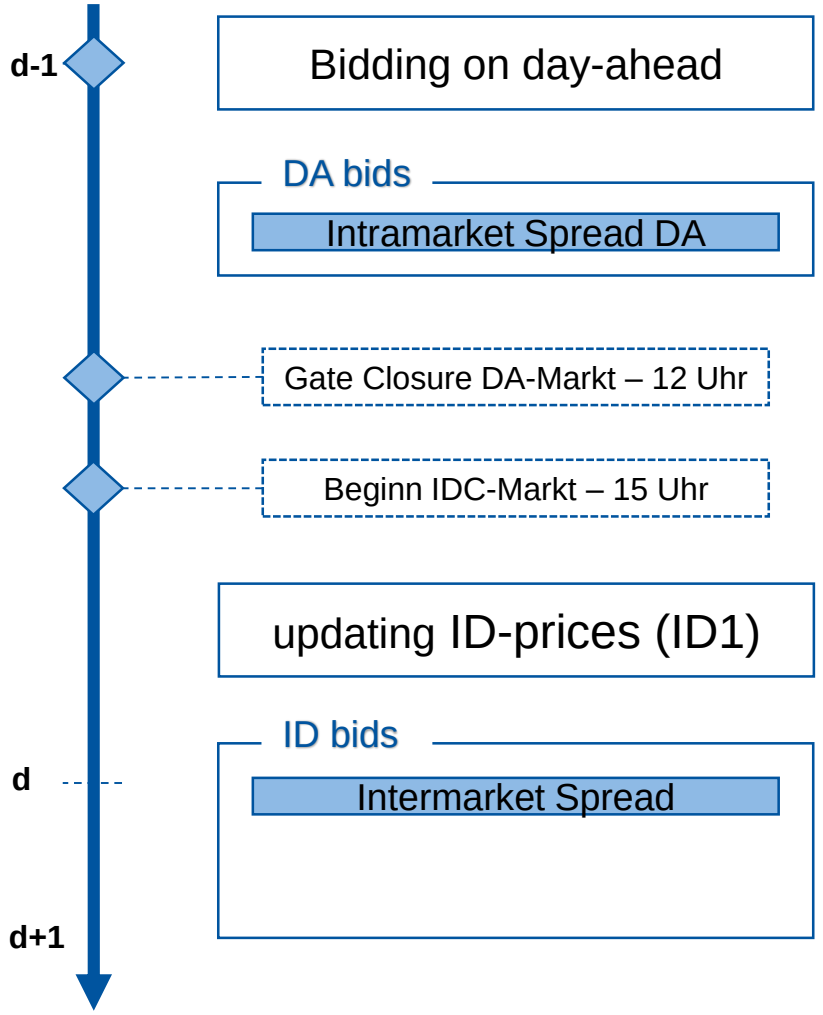

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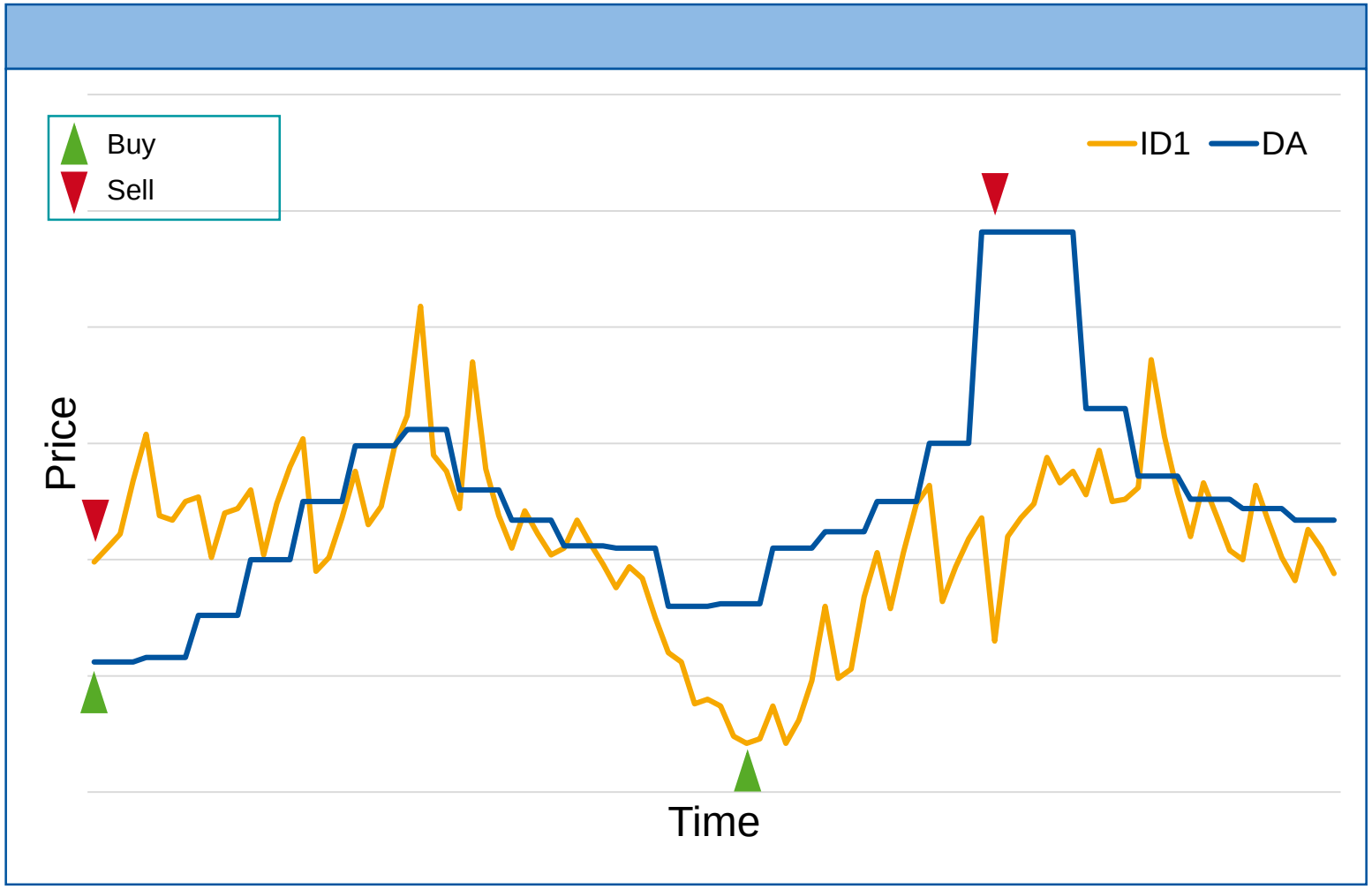

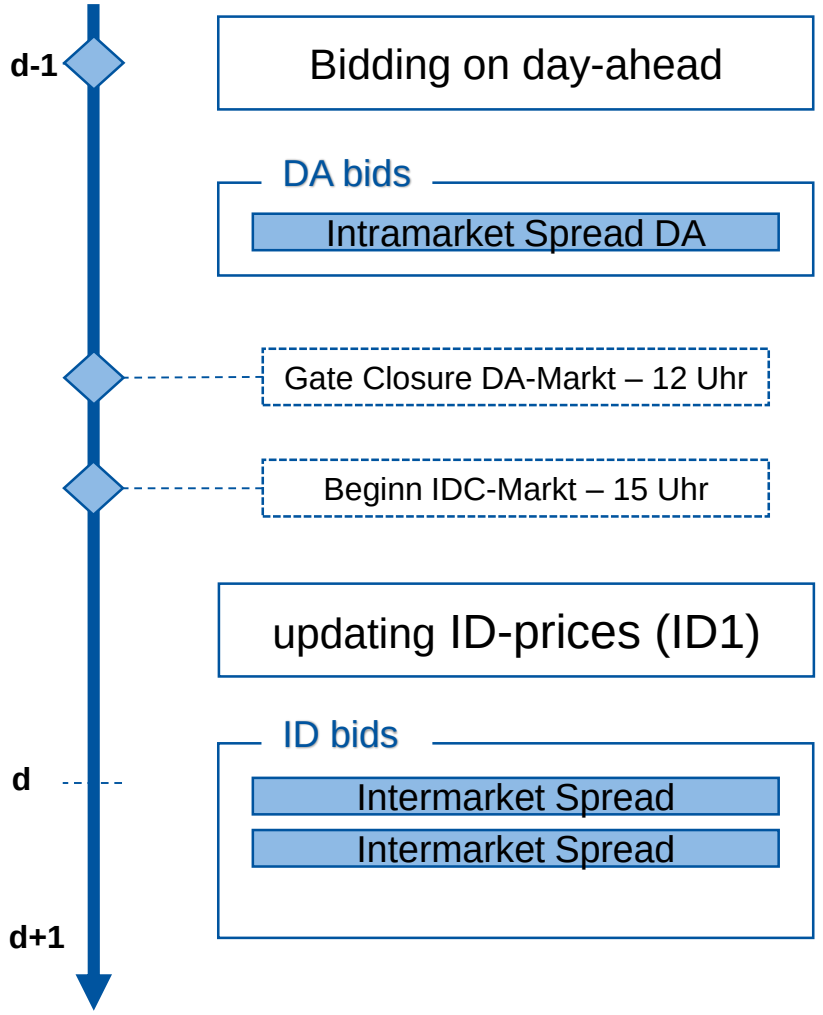

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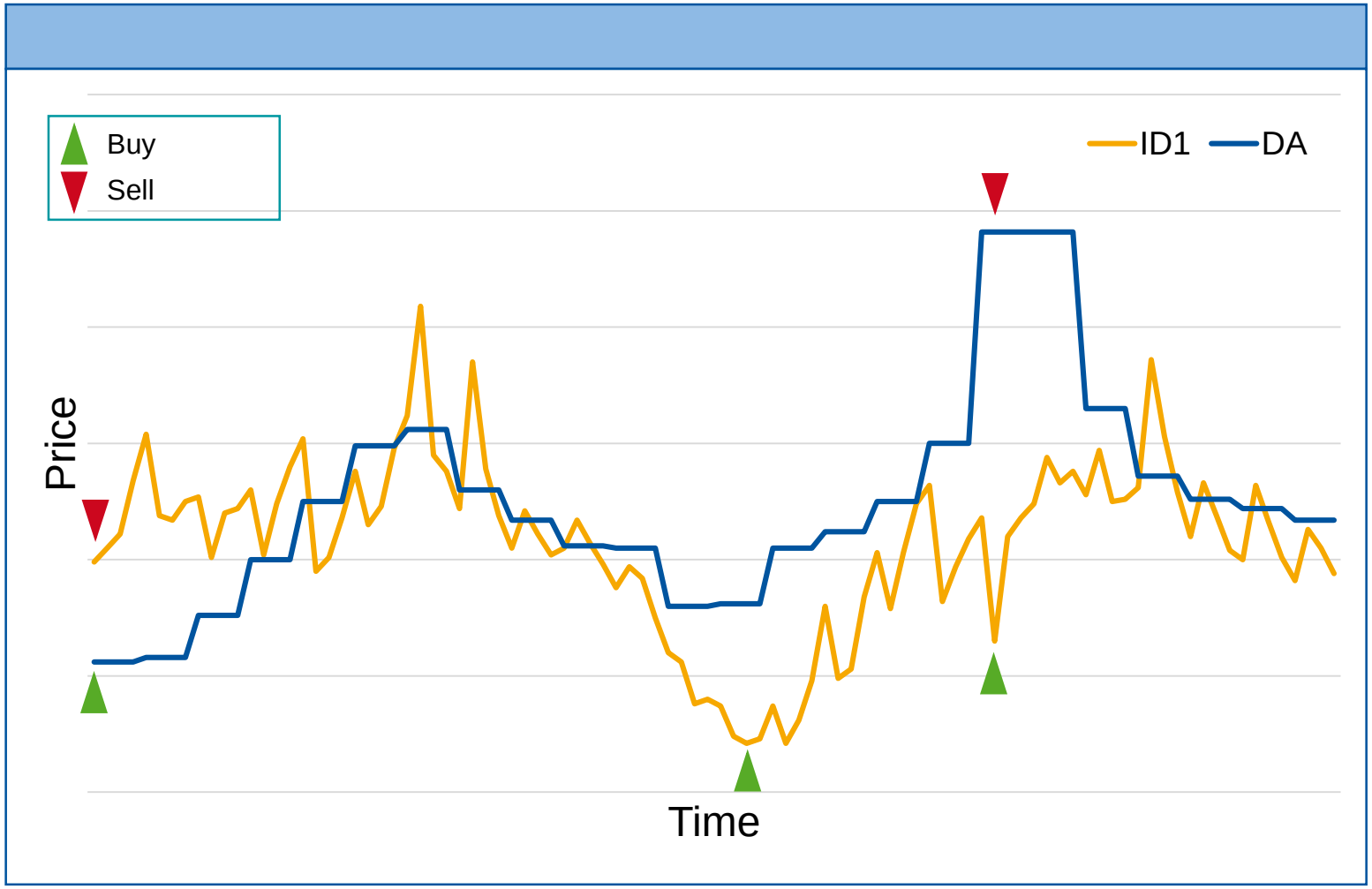

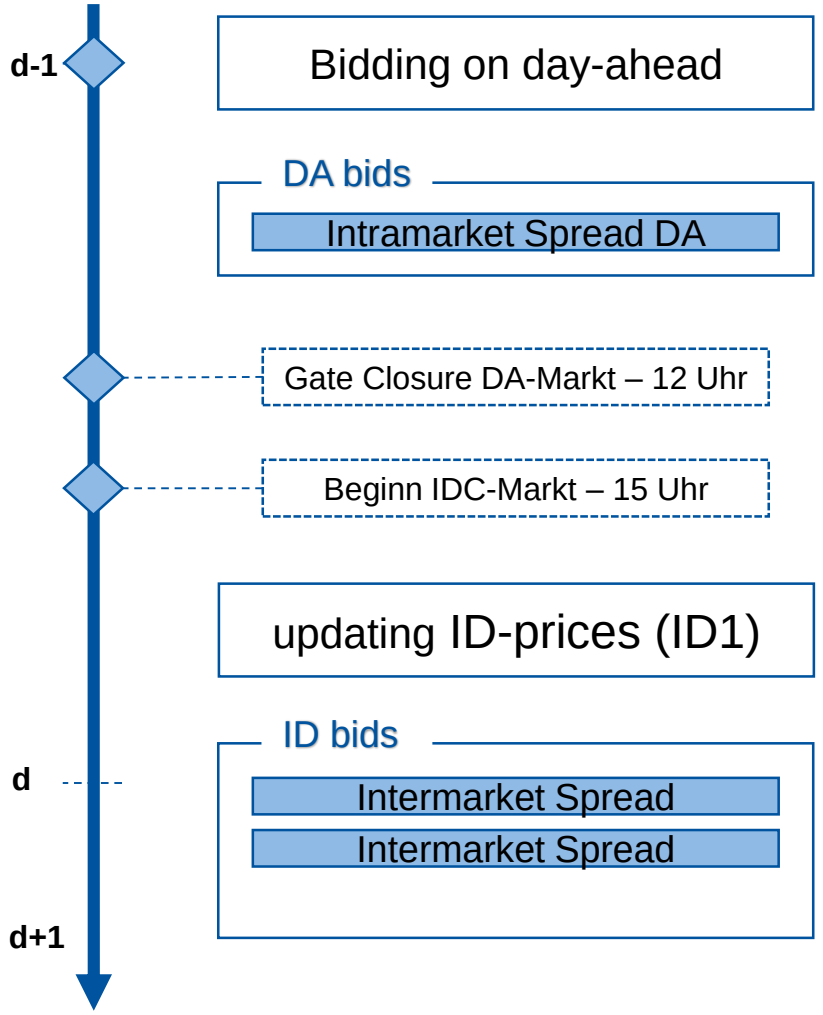

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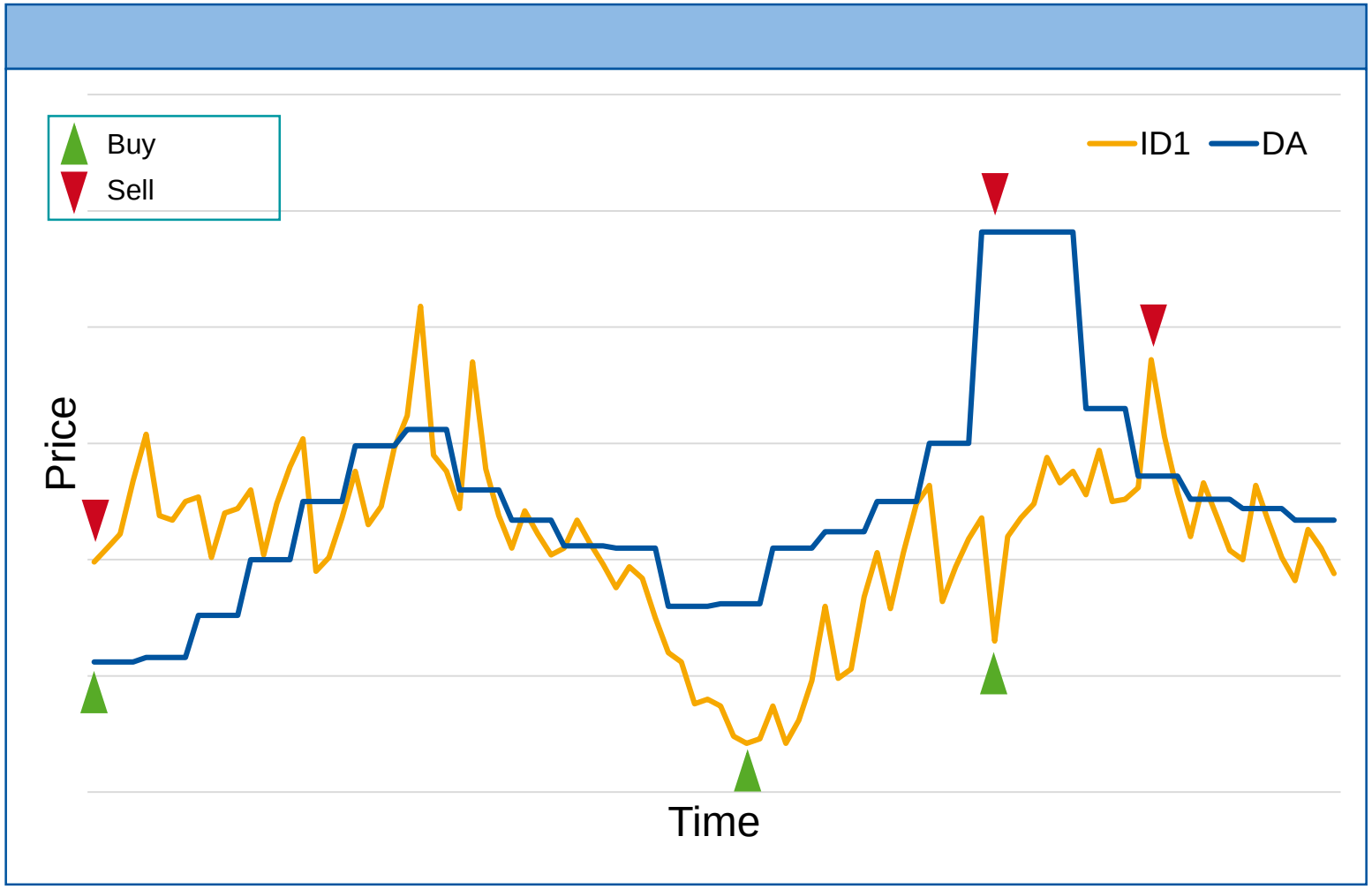

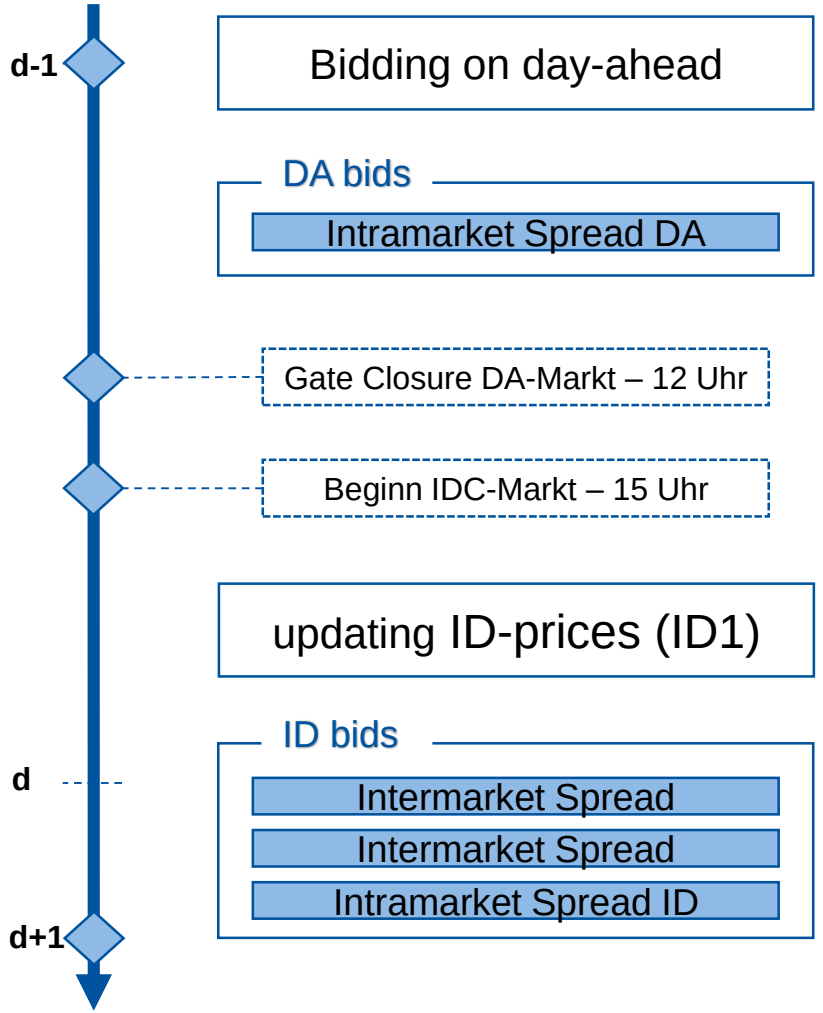

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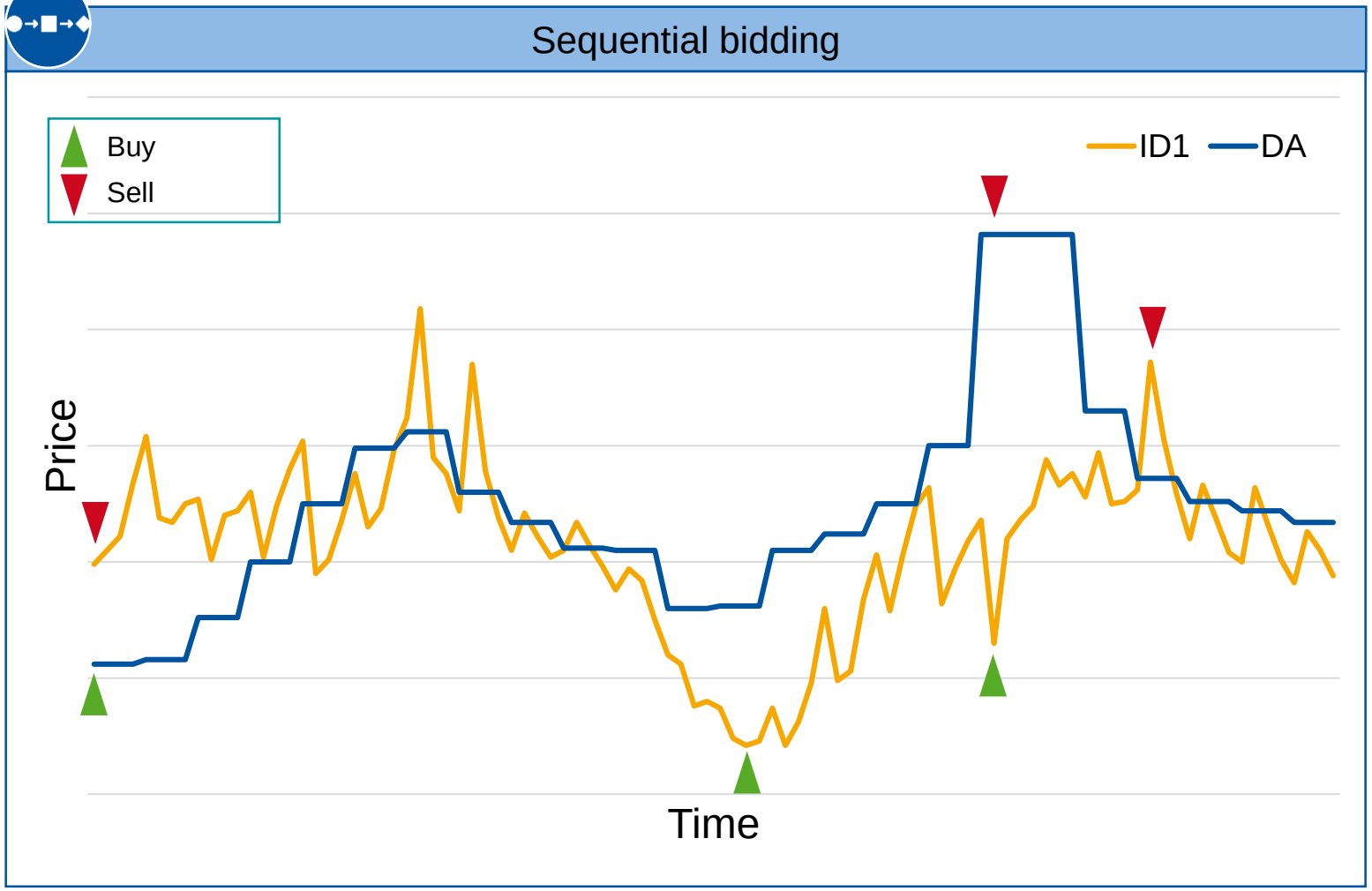
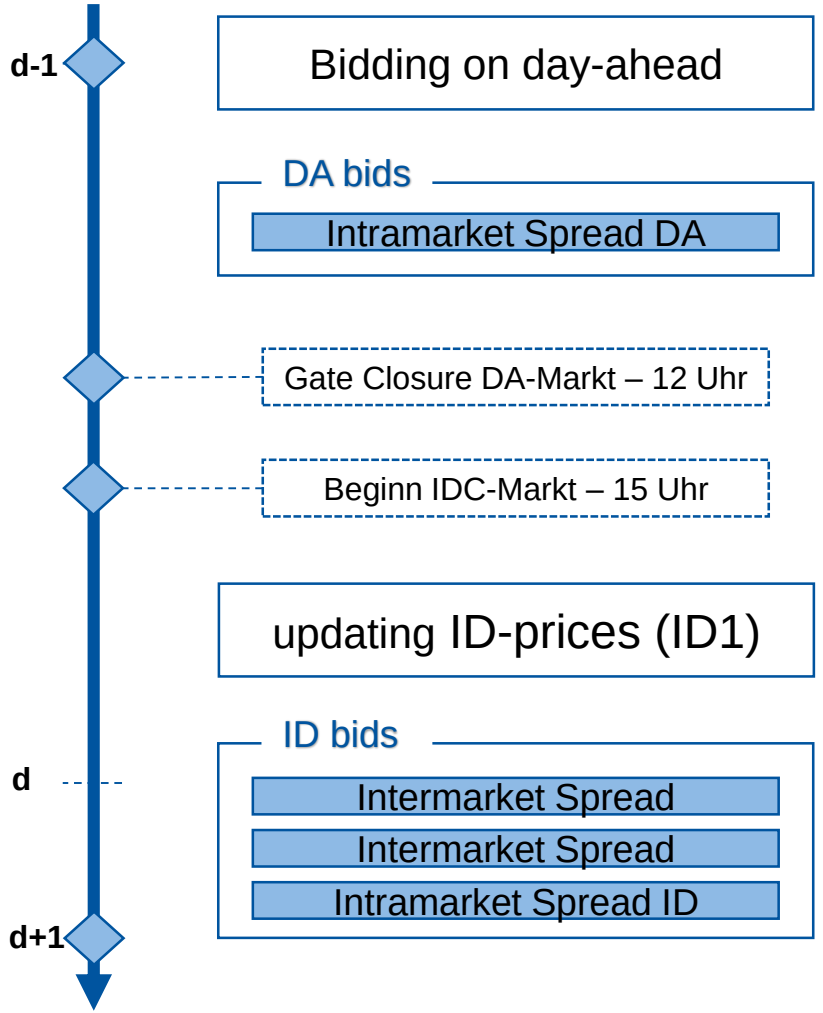


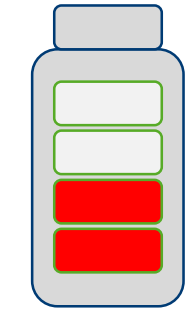


BACKUP: Market basics: FCR and aFRR

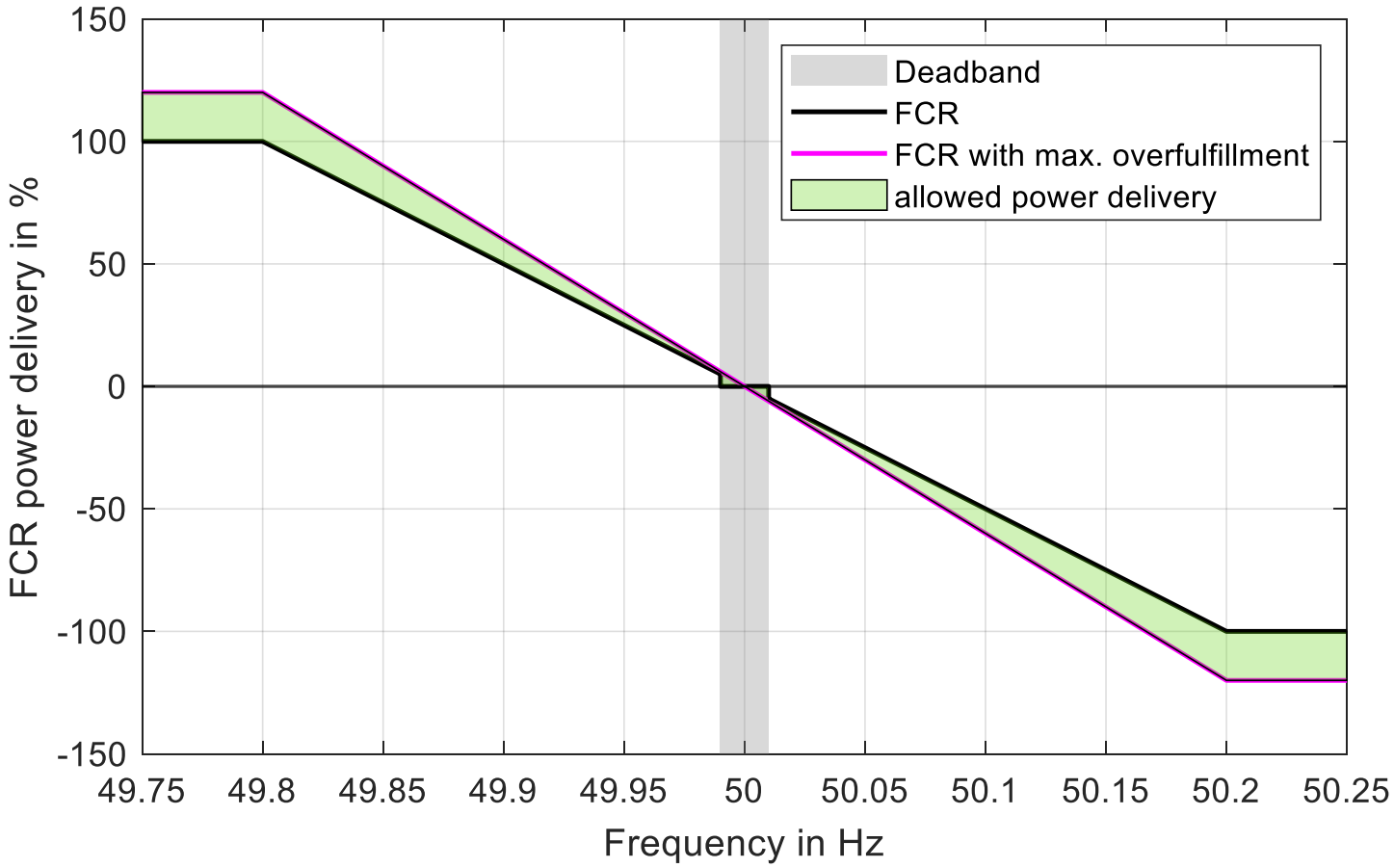
	Primary control reserve (FCR) (Frequency Containment Reserve)	**Secondary control reserve (aFRR)** (Automatic Frequency Restoration Reserve)
Activation	Automatic, decentralized based on the grid frequency	According to the set point specified by the transmission system operator
Activation period	Complete activation within 30 seconds	Complete activation within 5 minutes, first reaction after 30seconds
Characteristics	Symmetrical	Asymmetrical
Details	Capacity market: 4-h products (6 per day)	Capacity market: 4-h products Energy market: 15 min. products

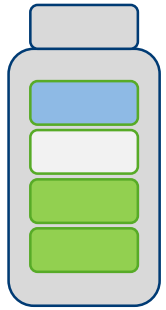
Source: https://www.regelleistung-online.de

BACKUP: Market basics: FCR (Frequency Containment Reserve)



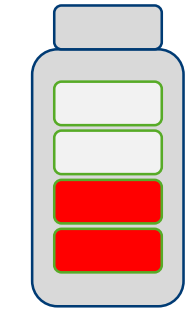
Charge





Discharge

BACKUP: Market basics: FCR (Frequency Containment Reserve)



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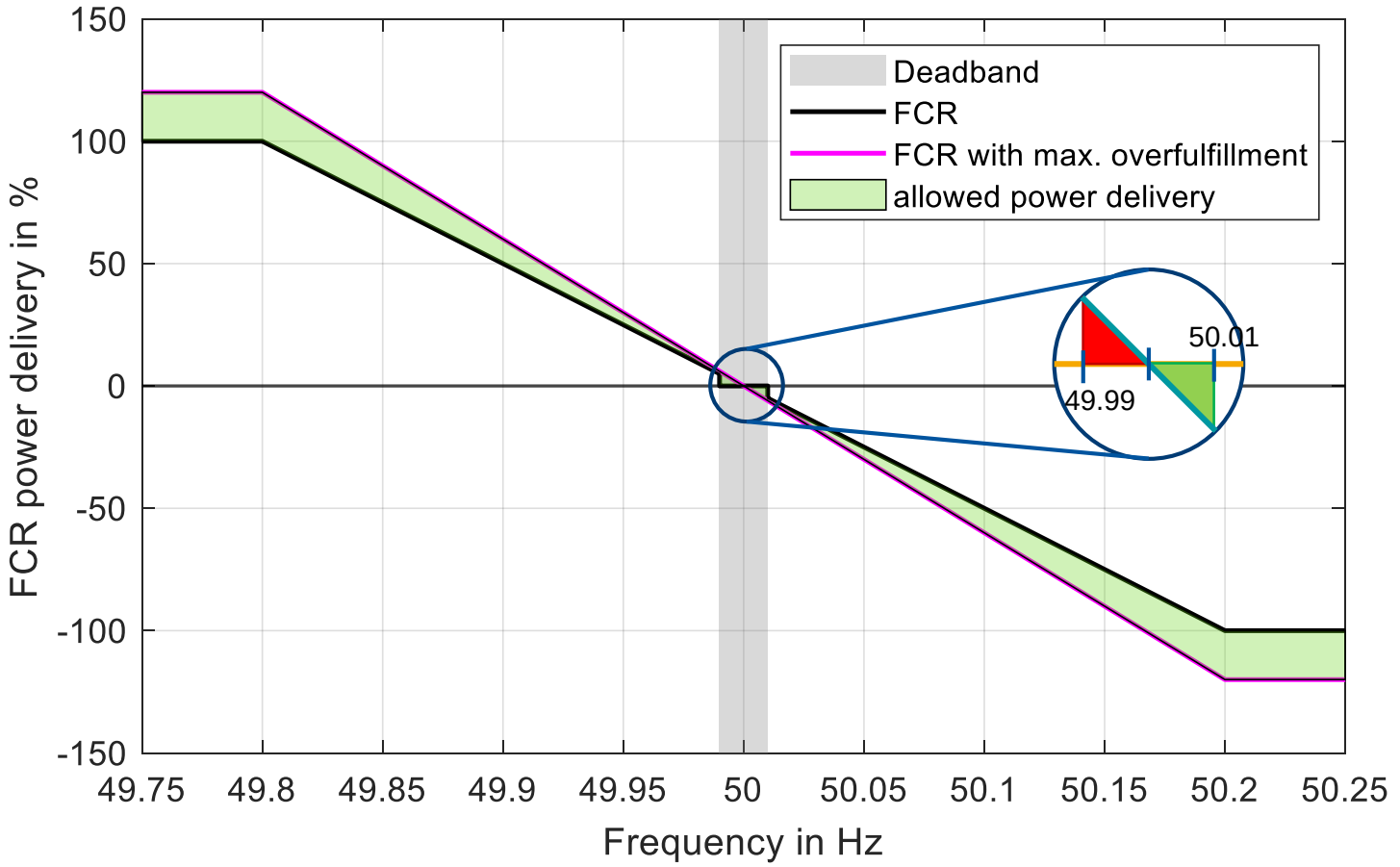

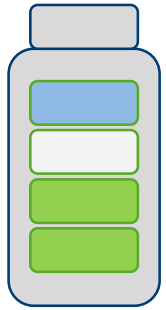

Discharge