Multi-Stage Stochastic Optimization for Battery Energy Storage Systems in the Iberian market

Smaranda Sgarciu | BTU Cottbus-Senftenberg
Smaranda.Sgarciu@b-tu.de

Syed Subhan Ahsen | Alberto Gallego | SMA Sunbelt Energy Gmbh

17.10.2022

IEEE PES
Power & Energy Society®

@ Thessaloniki, Greece, 17-19 Oct 2022

Motivation

- Global net zero emissions system → installed capacity for battery storage systems would reach 1,600 GW in 2050.
- The costs of battery energy storage systems is high → asset owners look for profit maximization opportunities.
- We investigate potential revenue streams of a price taker battery storage power plant owner which participates in the Iberian electricity market.

Energy Market Design

The Iberian electricity market design is comparable to those of other EU member states

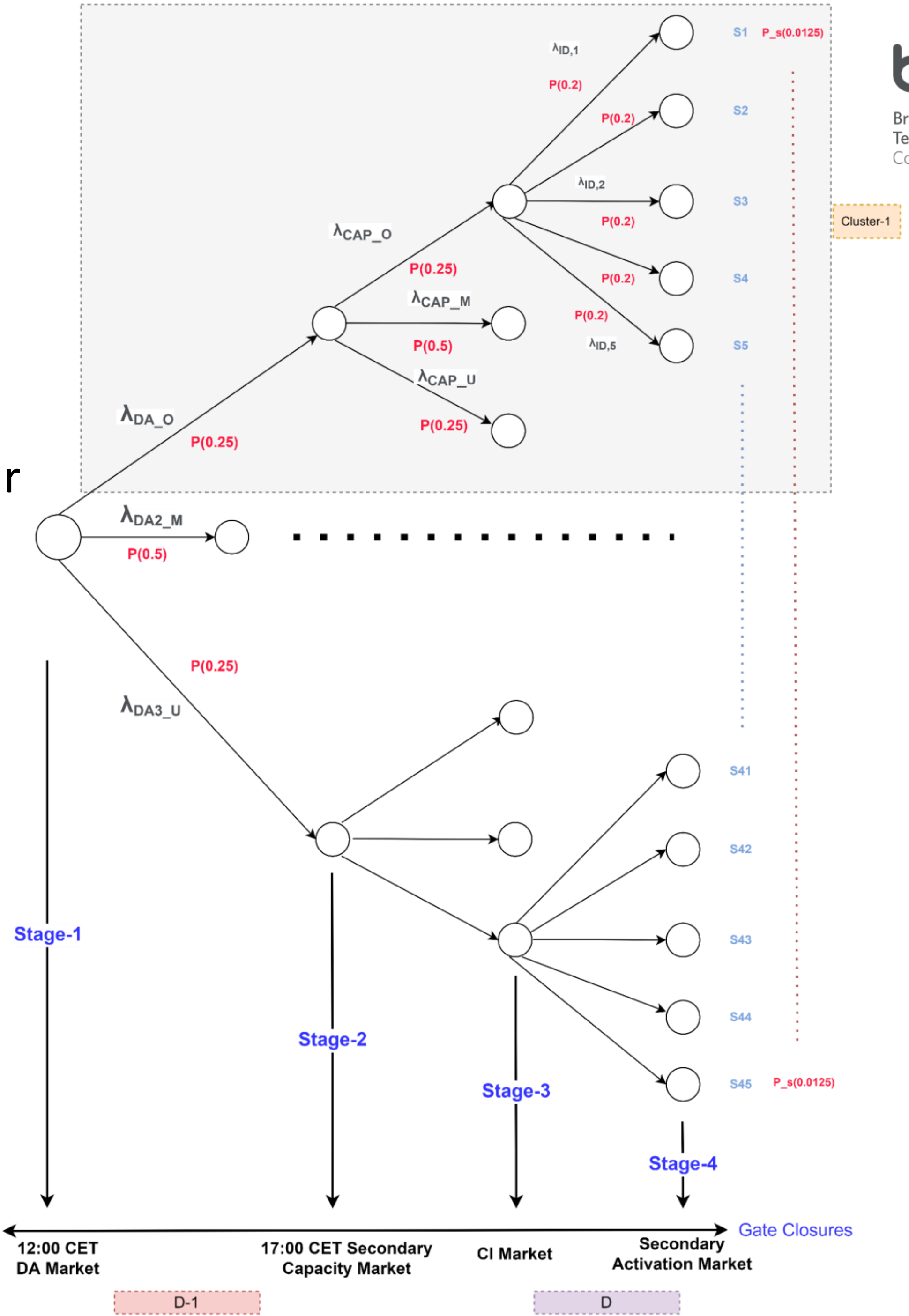
- The Day-Ahead Market: gate closes at 12:00 CET.
- The Intraday Market: the arrangement has 6 sessions - from 14:00 to 09:00 CET day+1.
- The Continuous Intraday Market: first round starts at 23:00. Adjustments can be done up to one hour before the actual delivery.
- The automatic Frequency Restoration Reserve Market – TSO publishes the upward and downward capacity requirement one day before delivery at 16:00

Methodology I

Multi-stage stochastic optimization

- Data extraction
- Forecasting module creates day-wise forecasts for one year
- Forecasts have 3-5 scenarios (quantiles 20-90%)
- Whole decision tree is written
- Scenarios and decision tree received → MILP formulation
- MILP – battery operation

  – energy market



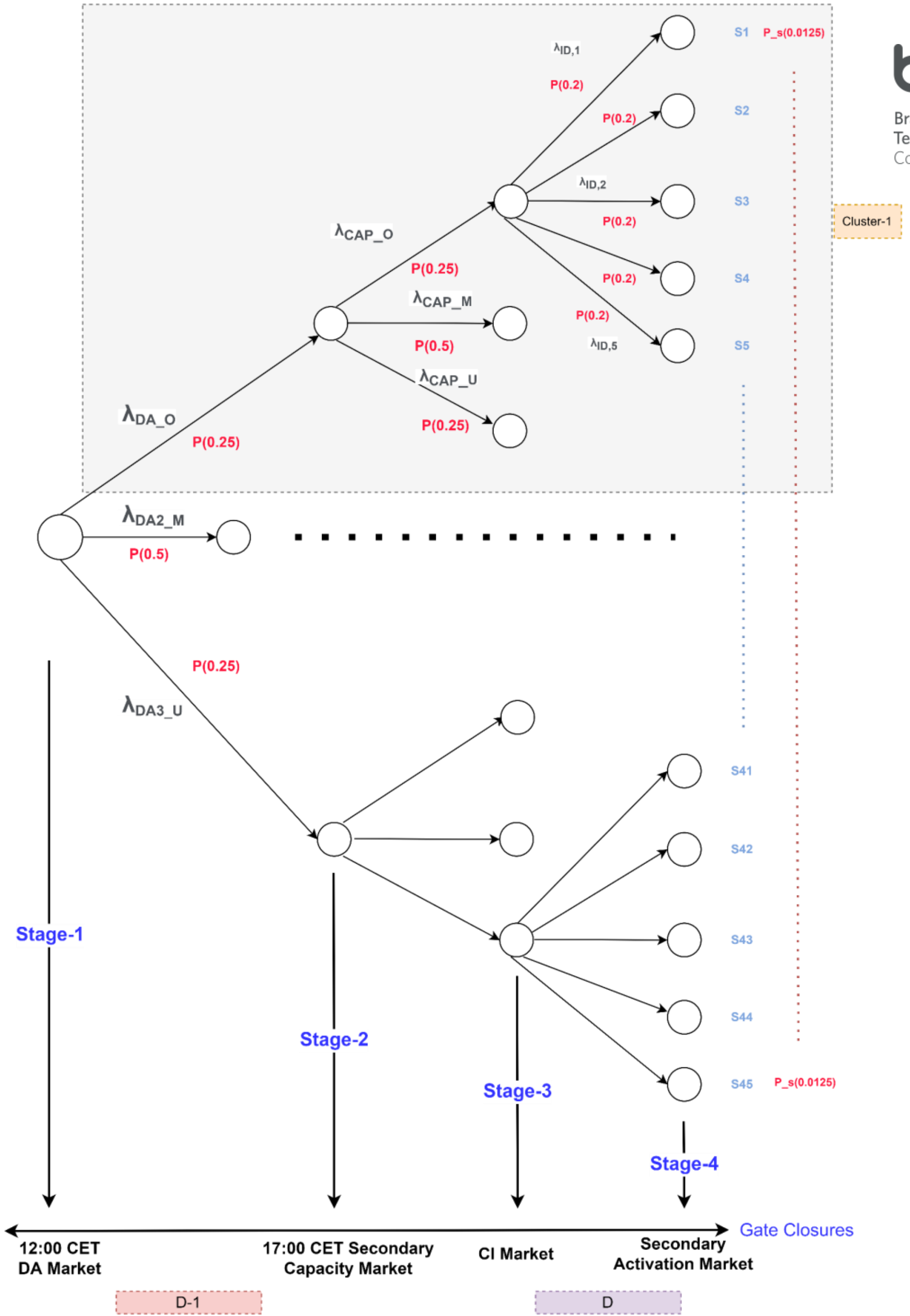
Methodology I

Multi-stage stochastic optimization

- The scenarios are generated using probabilistic forecasting technique for every price signal.
- The MILP model - mathematical formulation for BESS operation and the energy market.

$$\text{Max}\sum_{t=1}^{24} Stage\,1 + Stage2 + Stage3 + Stage4$$

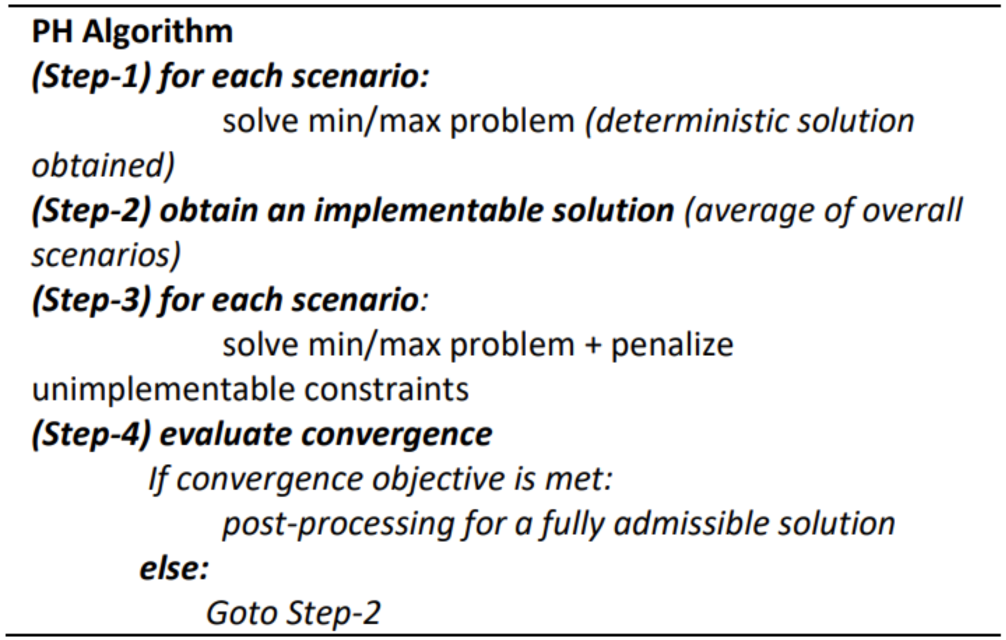
$$\text{Max}\sum_{t=1}^{24}\Big[\lambda_{DA}(t)\cdot\left(P_{DA}^{Bid+}(t) - P_{DA}^{Bid-}(t)\right)\cdot\Delta t + P_{band}^{Up+Dw}(t)\cdot\lambda_{AVAIL}(t) + \lambda_{ID}(t)\ \left(P_{CIM}^{Bid-}(t) - P_{CIM}^{Bid+}(t)\right)\cdot\Delta t + P_{aFRR}^{Up}(t)\cdot\lambda_{UP}(t)\cdot\Delta t - P_{aFRR}^{Dw}(t)\cdot\lambda_{DOWN}(t)\cdot\Delta t\Big]$$



Methodology II & III

Progressive Hedging Algorithm

- Used to overcome the problem of convergence.
- Progressive hedging algorithm uses a decomposition strategy to solve the problem.



```
PH Algorithm
(Step-1) for each scenario:
            solve min/max problem (deterministic solution obtained)
(Step-2) obtain an implementable solution (average of overall scenarios)
(Step-3) for each scenario:
            solve min/max problem + penalize unimplementable constraints
(Step-4) evaluate convergence
        If convergence objective is met:
            post-processing for a fully admissible solution
        else:
            Goto Step-2
```

Probabilistic Forecasting

1. Generate time series data.
2. Segregate into train and test datasets
3. Select a relevant algorithm
4. Adjust model hyperparameters
5. Add the number of sample paths
6. Evaluate the forecasts and compute scores

Selected KPIs

The Value of Stochastic Solution **(VSS)**

$$VSS = SS - EEV$$

Stochastic Solution

Expectation of the Expected Value Problem

Compares the advantage of incorporating uncertainty into the model

Expected value of Perfect Information **(EVPI)**

$$EVPI = WS - SS$$

Wait and See Solution

Stochastic Solution

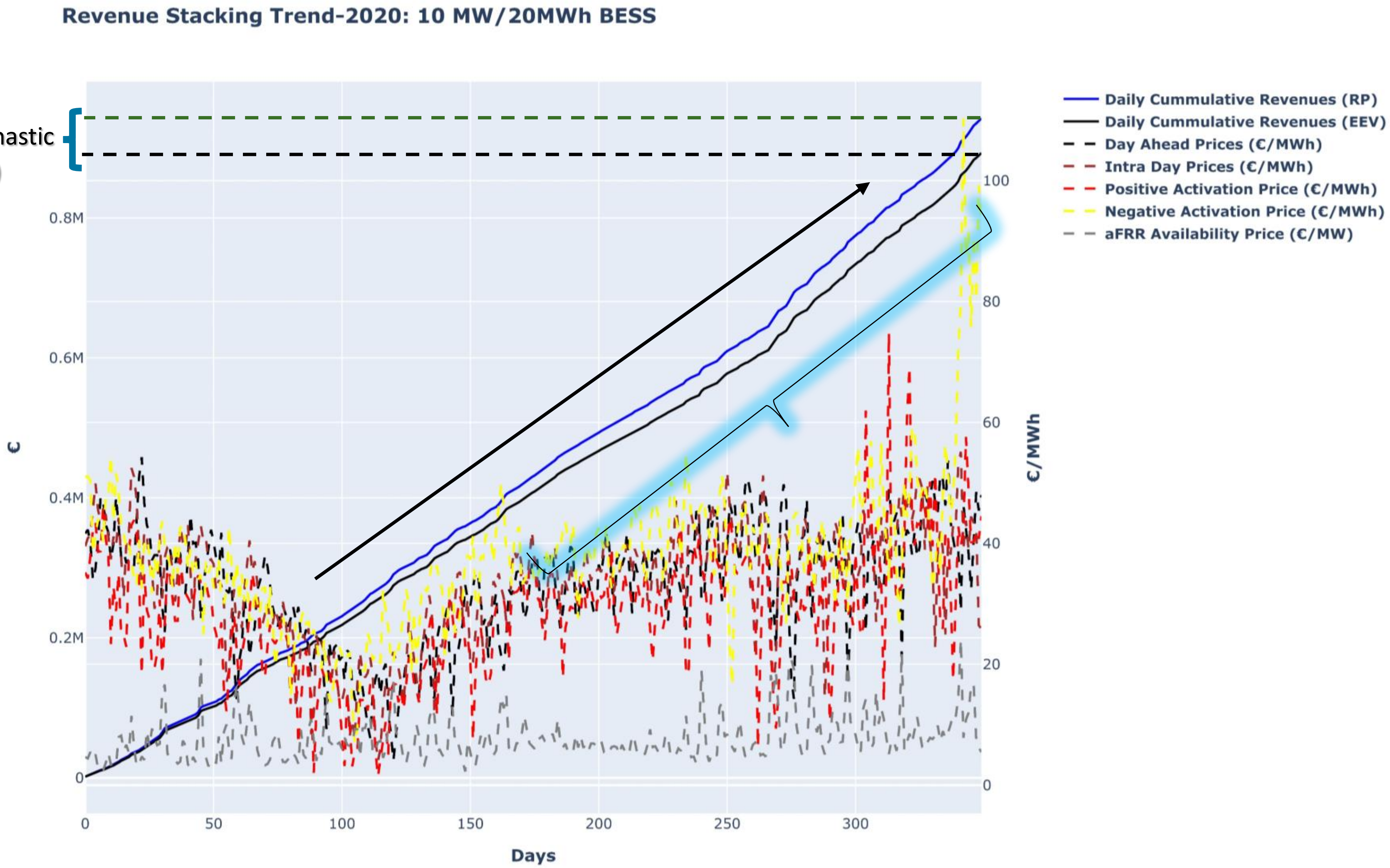
How much an investor would pay for having perfect information

Results – Selected KPIs

Value of Stochastic Solution (46k)

Selected KPIs

Year	EEV Solution [M€]	RP with PH [M€]	VSS [€]	WS [M€]	EVPI [€]
2020	0.89	0.94	46k	0.94	3k


Revenue Stacking Trend-2020: 10 MW/20MWh BESS

Thank you!

Smaranda Sgarciu

Smaranda.Sgarciu@b-tu.de