Sets / Params / Decision Variables

$T = \{0, 1, \dots, T-1\}$ $\quad \Delta t = 0.25$ (PTUs)

D ; PTU's in day d: $T_d \subset T$ (Days for max cycling constraint)

$0 \leq E_t \leq E^{max}$ (capacity bands)

$0 \leq P_t^{ch} \leq P^{max}$, $0 \leq P_t^{ds} \leq P^{max}$ (power bounds)

π_t^{short}, π_t^{long} (short & long price per PTU)

$\eta \in [0, 1]$ (round trip efficiency)

$E_0 = E_T = E^{init}$ (cyclic)

$R^{ch\uparrow}$, $R^{ch\downarrow}$, $R^{ds\uparrow}$, $R^{ds\downarrow}$ (ramping limits MW/PTU)

Cyc^{MAX} (Daily cycle cap EFC/day)

c^{deg} (Degradation costs €/MWh)

$E_t \in [E^{min}, E^{max}]$, $\forall t \in T$ (SOC)

$P_t^{ch} \in [0, P^{max}]$, $P^{ds} \in [0, P^{max}]$ $\forall t$ (charge discharge power)

$y_t^{ch} \in \{0, 1\}$, $y_t^{ds} \in \{0, 1\}$, $\forall t$ (commitment binaries)

Objective Function / Constraints

$$\max \sum_{t\in T} \Big(\underbrace{\pi^{long} P_t^{ds}}_{\text{discharge revenue}} - \underbrace{\pi^{short} P_t^{ch}}_{\text{charge cost}} \Big)\Delta t - \underbrace{c^{deg} \sum_{t\in T} \left(P_t^{ch} + P_t^{ds}\right)\Delta t}_{\text{degradation costs}}$$

→ handles dual pricing : worst case dischage settled at long price and charge settled at short price.

s.t.

$$y_t^{ch} + y_t^{ds} \le 1, \quad \forall t \in T \qquad \text{(mutual exclusivity)}$$

$$P_t^{ch} \le P^{max} y_t^{ch}, \quad P_t^{ds} \le P^{max} y_t^{ds}, \quad \forall t \qquad \text{(Linking)}$$

$$E_t = E_{t-1} + \eta P_{t-1}^{ch} \Delta t - P_{t-1}^{ds} \Delta t, \quad \forall t \in T \qquad \text{(SOC)}$$

$$E_0 = E_{init}, \quad E_{T-1} = E_{init} \qquad \text{(initial \& terminal)}$$

$$P_t^{ch} \le \frac{E_{max} - E_t}{\eta \Delta t}, \quad P_t^{ds} \le \frac{E_t}{\Delta t}, \quad \forall t \qquad \text{(no over charge / overdischage)}$$

$$\left.\begin{aligned} P_t^{ch} - P_{t-1}^{ch} &\le R^{ch\uparrow}, \quad P_{t-1}^{ch} - P_t^{ch} \le R^{ch}_{\downarrow}, \quad \forall t \neq 0 \\ P_t^{ds} - P_{t-1}^{ds} &\le R^{ds\uparrow}, \quad P_{t-1}^{ds} - P_t^{ds} \le R^{ds}_{\downarrow}, \quad \forall t \neq 0 \end{aligned}\right\} \text{(ramp limits)}$$

$$Thru_d = \sum_{t\in T_d} \left(P_t^{ch} + P_t^{ds}\right)\Delta t \Rightarrow Thru_d \le 2\, Cyc^{max} E^{max}, \quad \forall d \in D$$

→ Daily throughput (EFC/day) cap