Optimization of Hybrid Power Plants: When Is a Detailed Electrolyzer Model Necessary?

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Online Companion

The following companion is supplementary to the paper *Optimization of Hybrid Power Plants: When Is a Detailed Electrolyzer Model Necessary?* and provides the mathematical formulations of the MILP models with only two states (namely On-Off and On-Standby) in Section A and B, respectively. These are simplified models compared to the one proposed in Section III with three states of the electrolyzer. All nomenclature is defined in the main paper.

A. *The Simplified MILP with On-Off States*

This Section provides the MILP where the on and off states of the electrolyzer are only modeled.

$$
\begin{aligned}
\max_{\boldsymbol{\Omega}} \quad & \sum_{t\in\mathcal{T}} p_t\lambda_t^{\mathrm{DA}} + d_t\lambda^{\mathrm{h}} - z_t^{\mathrm{su}}\lambda^{\mathrm{su}} && && (1.1)\\
\text{s.t.} \quad & p_t = P_t^{\mathrm{w}} - p_t^{\mathrm{e}} - p_t^{\mathrm{c}} && \forall\, t\in\mathcal{T}, && (1.2)\\
& p_t^{\mathrm{e}} \le C^{\mathrm{e}} z_t^{\mathrm{oo}} && \forall\, t\in\mathcal{T}, && (1.3)\\
& p_t^{\mathrm{e}} \ge P^{\min} z_t^{\mathrm{oo}} && \forall\, t\in\mathcal{T}, && (1.4)\\
& z_t^{\mathrm{su}} \ge z_t^{\mathrm{oo}} - z_{t-1}^{\mathrm{oo}} && \forall\, t\in\mathcal{T}\setminus\{1\}, && (1.5)\\
& z_{t=1}^{\mathrm{su}} = 0, && && (1.6)\\
& h_t = \sum_{s\in\mathcal{S}} (A_s \hat{p}_{ts}^{\mathrm{e}} + B_s z_{ts}^{\mathrm{h}}) && \forall\, t\in\mathcal{T}, && (1.7)\\
& \underline{P}_s z_{ts}^{\mathrm{h}} \le \hat{p}_{ts}^{\mathrm{e}} \le \overline{P}_s z_{ts}^{\mathrm{h}} && \forall\, t\in\mathcal{T}, s\in\mathcal{S}, && (1.8)\\
& z_t^{\mathrm{oo}} = \sum_{s\in\mathcal{S}} z_{ts}^{\mathrm{h}} && \forall\, t\in\mathcal{T}, && (1.9)\\
& p_t^{\mathrm{e}} = \sum_{s\in\mathcal{S}} \hat{p}_{ts}^{\mathrm{e}} && \forall\, t\in\mathcal{T}, && (1.10)\\
& h_t = h_t^{\mathrm{d}} + s_t^{\mathrm{in}} && \forall\, t\in\mathcal{T}, && (1.11)\\
& d_t = h_t^{\mathrm{d}} + s_t^{\mathrm{out}} && \forall\, t\in\mathcal{T}, && (1.12)\\
& s_t^{\mathrm{out}} \le S^{\mathrm{out}} && \forall\, t\in\mathcal{T}, && (1.13)\\
& p_t^{\mathrm{c}} = K^{\mathrm{c}} s_t^{\mathrm{in}} && \forall\, t\in\mathcal{T}, && (1.14)\\
& s_{t=1} = S^{\mathrm{ini}} + s_{t=1}^{\mathrm{in}} - s_{t=1}^{\mathrm{out}}, && && (1.15)\\
& s_t = s_{t-1} + s_t^{\mathrm{in}} - s_t^{\mathrm{out}} && \forall\, t\in\mathcal{T}\setminus\{1\}, && (1.16)\\
& s_t \le C^{\mathrm{s}} && \forall\, t\in\mathcal{T}, && (1.17)\\
& \sum_{t\in\mathcal{H}_n} d_t \ge D_n^{\min} && \forall\, n\in\{1,...,N\}, && (1.18)\\
& d_t, h_t, h_t^{\mathrm{d}}, p_t, p_t^{\mathrm{c}}, \hat{p}_{ts}^{\mathrm{e}}, s_t, s_t^{\mathrm{in}}, s_t^{\mathrm{out}} \in \mathbb{R}^+, && && (1.19)\\
& z_t^{\mathrm{su}}, z_{ts}^{\mathrm{h}}, z_t^{\mathrm{oo}} \in \{0,1\}, && && (1.20)\\
& \Omega = \{d_t, h_t, h_t^{\mathrm{d}}, p_t, p_t^{\mathrm{c}}, \hat{p}_{ts}^{\mathrm{e}}, s_t^{\mathrm{in}}, s_t^{\mathrm{out}}, z_t^{\mathrm{su}}, z_{ts}^{\mathrm{h}}, z_t^{\mathrm{oo}}\}. && && (1.21)
\end{aligned}
$$

B. The Simplified MILP with On-Standby States

This Section presents the simplified MILP taking into account only the on and standby states of the electrolyzer.

$$
\begin{aligned}
\max_{\Gamma} \quad & \sum_{t\in\mathcal{T}} p_t\lambda_t^{\mathrm{DA}} + d_t\lambda^{\mathrm{h}} - p_t^{\mathrm{in}}\lambda_t^{\mathrm{in}} && && (2.1)\\
\text{s.t.} \quad & p_t = P_t^{\mathrm{w}} + p_t^{\mathrm{in}} - p_t^{\mathrm{e}} - p_t^{\mathrm{c}} && \forall\, t\in\mathcal{T}, && (2.2)\\
& p_t^{\mathrm{in}} \le P^{\mathrm{sb}}(1-z_t^{\mathrm{os}}) && \forall\, t\in\mathcal{T}, && (2.3)\\
& p_t^{\mathrm{e}} \le C^{\mathrm{e}} z_t^{\mathrm{os}} + P^{\mathrm{sb}}(1-z_t^{\mathrm{os}}) && \forall\, t\in\mathcal{T}, && (2.4)\\
& p_t^{\mathrm{e}} \ge P^{\mathrm{min}} z_t^{\mathrm{os}} + P^{\mathrm{sb}}(1-z_t^{\mathrm{os}}) && \forall\, t\in\mathcal{T}, && (2.5)\\
& h_t = \sum_{s\in\mathcal{S}} (A_s\hat{p}_{ts}^{\mathrm{e}} + B_s z_{ts}^{\mathrm{h}}) && \forall\, t\in\mathcal{T}, && (2.6)\\
& \underline{P}_s z_{ts}^{\mathrm{h}} \le \hat{p}_{ts}^{\mathrm{e}} \le \overline{P}_s z_{ts}^{\mathrm{h}} && \forall\, t\in\mathcal{T}, s\in\mathcal{S}, && (2.7)\\
& z_t^{\mathrm{os}} = \sum_{s\in\mathcal{S}} z_{ts}^{\mathrm{h}} && \forall\, t\in\mathcal{T}, && (2.8)\\
& p_t^{\mathrm{e}} = \sum_{s\in\mathcal{S}} \hat{p}_{ts}^{\mathrm{e}} + P^{\mathrm{sb}}(1-z_t^{\mathrm{os}}) && \forall\, t\in\mathcal{T}, && (2.9)\\
& h_t = h_t^{\mathrm{d}} + s_t^{\mathrm{in}} && \forall\, t\in\mathcal{T}, && (2.10)\\
& d_t = h_t^{\mathrm{d}} + s_t^{\mathrm{out}} && \forall\, t\in\mathcal{T}, && (2.11)\\
& s_t^{\mathrm{out}} \le S^{\mathrm{out}} && \forall\, t\in\mathcal{T}, && (2.12)\\
& p_t^{\mathrm{c}} = K^{\mathrm{c}} s_t^{\mathrm{in}} && \forall\, t\in\mathcal{T}, && (2.13)\\
& s_{t=1} = S^{\mathrm{ini}} + s_{t=1}^{\mathrm{in}} - s_{t=1}^{\mathrm{out}} && && (2.14)\\
& s_t = s_{t-1} + s_t^{\mathrm{in}} - s_t^{\mathrm{out}} && \forall\, t\in\mathcal{T}\setminus\{1\}, && (2.15)\\
& s_t \le C^{\mathrm{s}} && \forall\, t\in\mathcal{T}, && (2.16)\\
& \sum_{t\in\mathcal{H}_n} d_t \ge D_n^{\mathrm{min}} && \forall\, n\in\{1,...,N\}, && (2.17)\\
& d_t, h_t, h_t^{\mathrm{d}}, p_t, p_t^{\mathrm{c}}, p_t^{\mathrm{in}}, \hat{p}_{ts}^{\mathrm{e}}, s_t, s_t^{\mathrm{in}}, s_t^{\mathrm{out}} \in \mathbb{R}^+, && && (2.18)\\
& z_{ts}^{\mathrm{h}}, z_t^{\mathrm{os}} \in \{0,1\}, && && (2.19)\\
& \Gamma = \{d_t, h_t, h_t^{\mathrm{d}}, p_t, p_t^{\mathrm{c}}, p_t^{\mathrm{in}}, \hat{p}_{ts}^{\mathrm{e}}, s_t^{\mathrm{in}}, s_t, s_t^{\mathrm{out}}, z_t^{\mathrm{su}}, z_t^{\mathrm{os}}\}. && && (2.20)
\end{aligned}
$$