Theoretical derivation and detailed explanation of (37)

--Section V.A Controlled evolution-based day-ahead decision correction

The day-ahead decision results, $\hat{x}_{g,t}$, $\hat{p}_{c,t}^{\text{cap}}$, obtained by the day-ahead decision model (see Section IV.B for details) implicitly assume that renewable energy in all periods within the day can be observed simultaneously. However, due to the uncertainty of renewable energy, during the intraday operation of period t, the renewable generation power after period t is unknown, which is the nonanticipativity constraint of intraday decision-making. Therefore, the day-ahead decision results must take into account the nonanticipativity constraints of intraday decision-making.

To this end, we construct the evolution model shown in (36) based on the nonanticipativity constraints (for simulating the multi-stage intraday decision-making process). The dual problem of (36) can be written as follows:

$$
\begin{aligned}
Q = \max \quad & \sum\nolimits_{g\in\Omega_{\text{SG}}} \left\{ \begin{array}{l} \alpha_{g,t}^{+}\hat{x}_{g,t}p_g^{\min} + \alpha_{g,t}^{-}\hat{x}_{g,t}p_g^{\max} \\ -\beta_{g,t}^{+}\cdot\left[RD_g\hat{x}_{g,t+1} + p_g^{\max}(1-\hat{x}_{g,t+1})\right] \\ -\beta_{g,t}^{-}\cdot\left[RU_g\hat{x}_{g,t} + p_g^{\max}(1-\hat{x}_{g,t})\right] \end{array} \right\} + \sum\nolimits_{c\in\Omega_{\text{CL}}} \gamma_{c,t}^{-}\hat{p}_{c,t}^{\text{cap}} + \chi \\
\text{s.t.} \quad & \alpha_{g,t}^{+} \ge 0, \alpha_{g,t}^{-} \le 0, \beta_{g,t}^{+} \ge 0,\ \beta_{g,t}^{-} \ge 0, \gamma_{c,t}^{-} \le 0, \\
& \text{other constraints independent of } \hat{x}_{g,t+1} \text{ and } \hat{p}_{c,t}^{\text{cap}}
\end{aligned}
$$

where χ is a linear expression independent of $\hat{x}_{g,t}$, and $\hat{p}_{c,t}^{\text{cap}}$. Additionally, the sub-gradient of Q at $\hat{x}_{g,t}$ is

$$
s_{g,t}^{UC} = \alpha_{g,t}^{+}p_g^{\min} + \alpha_{g,t}^{-}p_g^{\max} - \beta_{g,t}^{+}\left(RD_g - p_g^{\max}\right) - \beta_{g,t}^{-}\left(RU_g - p_g^{\max}\right),
$$

and the sub-gradient of Q at $\hat{p}_{c,t}^{\text{cap}}$ is

$$
s_{c,t}^{DR} = \gamma_{c,t}^{-}.
$$

Sub-gradients $s_{g,t}^{UC}$ and $s_{c,t}^{DR}$ provide the feasible descent direction for the day-ahead decisions $\hat{x}_{g,t}$, and $\hat{p}_{c,t}^{\text{cap}}$, respectively.

Noted that $\hat{L}_{t,i}^{PUN} > 0$ indicates that the current decisions cause operation infeasibility under adverse scenario $\tilde{p}_{r,i}$. Therefore, for scenarios $\tilde{p}_{r,i} \in \Omega_{\text{W}}$. and periods $\text{t} \in \Omega_{\text{T}}$ where $\hat{L}_{t,i}^{PUN} > 0$, the cutting planes for correcting the day-ahead decisions $\hat{x}_{g,t}$, $\hat{p}_{c,t}^{\text{cap}}$ can be constructed as follows:

$$
\sum\nolimits_{g\in\Omega_{\text{SG}}} \begin{bmatrix} \hat{\alpha}_{g,t}^{-}p_g^{\max} + \hat{\alpha}_{g,t}^{+}p_g^{\min} \\ +\hat{\beta}_{g,t}^{+}(p_g^{\max} - RD_g) \\ +\hat{\beta}_{g,t}^{-}(p_g^{\max} - RU_g) \end{bmatrix} \cdot \left(x_{g,t} - \hat{x}_{g,t}\right) + \sum\nolimits_{c\in\Omega_{\text{CL}}} \hat{\gamma}_{c,t}^{-}\left(p_{c,t}^{\mathbf{cap}} - \hat{p}_{c,t}^{\mathbf{cap}}\right) \le -\hat{L}_{t,i}^{\mathbf{PUN}}
$$

which can be used to correct the day-ahead decisions $\hat{x}_{g,t}$, $\hat{p}_{c,t}^{\text{cap}}$ for mitigating the punish cost. By adding the above functions into Ω_{CUT} and re-solving the optimization model (35) in day-ahead decision layer, the day-ahead decisions can be improved to ensure feasibility.