DER Models

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1 Without Storage

1.1 Disaggregation

$$\begin{aligned}
\textit{max} \quad & \sum_{t\in T}\left(P_t^{DA}x_{it}+\mathbb{E}\left[P_t^{RT}(\xi)y_{it}^{+}(\xi)-P_t^{PN}y_{it}^{-}(\xi)\right]\right) && \textit{(1a)}\\
\textit{s.t.} \quad & R_{it}(\xi)-x_{it}=y_{it}^{+}(\xi)-y_{it}^{-}(\xi) \quad \forall t\in T && \textit{(1b)}\\
& R_{it}(\xi)\geqslant y_{it}^{+}(\xi) \quad \forall t\in T && \textit{(1c)}\\
& y_{it}^{+}(\xi)\leqslant Mz_{it}(\xi), \quad y_{it}^{-}(\xi)\leqslant M(1-z_{it}(\xi)) \quad \forall t\in T && \textit{(1d)}\\
& x_{it}^{DA}\geqslant 0, y_{it}^{+}(\xi)\geqslant 0, y_{it}^{-}(\xi)\geqslant 0, z_{it}(\xi)\in\{0,1\} \quad \forall t\in T && \textit{(1e)}
\end{aligned}$$

1.2 Aggregation

$$\begin{aligned}
\textit{max} \quad & \sum_{t\in T}\left(P_t^{DA}\alpha_{t}+\mathbb{E}\left[P_t^{RT}(\xi)\beta_{t}^{+}(\xi)-P_t^{PN}\beta_{t}^{-}(\xi)\right]\right) && \textit{(2a)}\\
\textit{s.t.} \quad & \sum_{i\in I}R_{it}(\xi)-\alpha_t=\beta_{t}^{+}(\xi)-\beta_{t}^{-}(\xi) \quad \forall t\in T && \textit{(2b)}\\
& \sum_{i\in I}R_{it}(\xi)\geqslant \beta_{t}^{+}(\xi) \quad \forall t\in T && \textit{(2c)}\\
& \beta_{t}^{+}(\xi)\leqslant Mz_t(\xi), \quad \beta_{t}^{-}(\xi)\leqslant M(1-z_t(\xi)) \quad \forall t\in T && \textit{(2d)}\\
& \alpha_t^{DA}\geqslant 0, \beta_{t}^{+}(\xi)\geqslant 0, \beta_{t}^{-}(\xi)\geqslant 0, z_t(\xi)\in\{0,1\} \quad \forall t\in T && \textit{(2e)}
\end{aligned}$$

1.3 Settlement

$$\begin{aligned}
\textit{max} \quad & \sum_{t\in T}\left(P_t^{DA}\alpha_{t}+\mathbb{E}\left[P_t^{RT}(\xi)\beta_{t}^{+}(\xi)-P_t^{PN}\beta_{t}^{-}(\xi)\right]\right) && \textit{(3a)}\\
\textit{s.t.} \quad & \sum_{i\in I}R_{it}(\xi)-\alpha_t^{DA}=\beta_{t}^{+}(\xi)-\beta_{t}^{-}(\xi) \quad \forall t\in T && \textit{(3b)}\\
& \sum_{i\in I}R_{it}(\xi)\geqslant \beta_{t}^{+}(\xi) \quad \forall t\in T && \textit{(3c)}\\
& \beta_{t}^{+}(\xi)\leqslant Mz_t(\xi), \quad \beta_{t}^{-}(\xi)\leqslant M(1-z_t(\xi)) \quad \forall t\in T && \textit{(3d)}\\
& \alpha_t=\sum_{i\in I}x_{it}(\xi), \quad \beta_{t}^{+}(\xi)=\sum_{i\in I}e_{it}^{+}(\xi), \quad \beta_{t}^{-}(\xi)=\sum_{i\in I}e_{it}^{-}(\xi) \quad \forall t\in T && \textit{(3e)}\\
& R_{it}(\xi)-x_{it}(\xi)=y_{it}^{+}(\xi)-y_{it}^{-}(\xi) \quad \forall t\in T && \textit{(3f)}\\
& R_{it}(\xi)\geqslant y_{it}^{+}(\xi) \quad \forall t\in T && \textit{(3g)}\\
& y_{it}^{+}(\xi)\leqslant Mz_{it}(\xi), \quad y_{it}^{-}(\xi)\leqslant M(1-z_{it}(\xi)) \quad \forall t\in T && \textit{(3h)}\\
& \sum_{j\in I,j\neq i}d_{ijt}(\xi)\leqslant y_{it}^{+}(\xi), \quad \sum_{j\in I,j\neq i}d_{jit}(\xi)\leqslant y_{it}^{-}(\xi) \quad \forall t\in T && \textit{(3i)}\\
& d_{iit}(\xi)=0 \quad \forall t\in T && \textit{(3j)}\\
& e_{it}^{+}(\xi)=y_{it}^{+}(\xi)-\sum_{j\in I,j\neq i}d_{ijt}(\xi) \quad \forall t\in T && \textit{(3k)}\\
& e_{it}^{-}(\xi)=y_{it}^{-}(\xi)-\sum_{j\in I,j\neq i}d_{jit}(\xi) \quad \forall t\in T && \textit{(3l)}
\end{aligned}$$

2 With Storage

2.1 Disaggregation

$$\max \quad \sum_{t\in T}\left(P_t^{DA}x_{it}+\mathbb{E}\left[P_t^{RT}(\xi)y_{it}^{+}(\xi)-P_t^{PN}y_{it}^{-}(\xi)\right]\right) \tag{4a}$$

$$\text{s.t.} \quad R_{it}(\xi)-x_{it}=y_{it}^{+}(\xi)-y_{it}^{-}(\xi)+z_{it}^{C}(\xi)-z_{it}^{D}(\xi) \quad \forall i,t \tag{4b}$$

$$R_{it}(\xi)\geqslant y_{it}^{+}(\xi) \quad \forall i,t \tag{4c}$$

$$z_{i,t+1}(\xi)=z_{it}(\xi)+z_{it}^{C}(\xi)-z_{it}^{D}(\xi) \quad \forall i,t \tag{4d}$$

$$z_{it}^{D}(\xi)\leqslant z_{it}(\xi) \quad \forall i,t \tag{4e}$$

$$z_{it}^{C}(\xi)\leqslant K_i-z_{it}(\xi) \quad \forall i,t \tag{4f}$$

$$0\leqslant z_{it}(\xi)\leqslant K_i \quad \forall i,t \tag{4g}$$

$$y_{it}^{+}(\xi)\leqslant M_1\rho_{it}(\xi), \quad y_{it}^{-}(\xi)\leqslant M_1(1-\rho_{it}(\xi)) \quad \forall i,t \tag{4h}$$

$$y_{it}^{-}(\xi)\leqslant M_1\delta_{it}(\xi), \quad z_{it}^{C}(\xi)\leqslant M_1(1-\delta_{it}(\xi)) \quad \forall i,t \tag{4i}$$

$$z_{it}^{C}(\xi)\leqslant M_1\zeta_{it}(\xi), \quad z_{it}^{D}(\xi)\leqslant M_1(1-\zeta_{it}(\xi)) \quad \forall i,t \tag{4j}$$

2.2 Aggregation

$$\max \quad \sum_{t\in T}\left(P_t^{DA}\alpha_t+\mathbb{E}\left[P_t^{RT}(\xi)\beta_t^{+}(\xi)-P_t^{PN}\beta_t^{-}(\xi)\right]\right) \tag{5a}$$

$$\text{s.t.} \quad \sum_{i\in I}R_{it}(\xi)-\alpha_t=\beta_t^{+}(\xi)-\beta_t^{-}(\xi)+\gamma_t^{C}(\xi)-\gamma_t^{D}(\xi) \quad \forall t \tag{5b}$$

$$\sum_{i\in I}R_{it}(\xi)\geqslant \beta_t^{+}(\xi) \quad \forall t \tag{5c}$$

$$\gamma_t^{D}(\xi)\leqslant \gamma_t(\xi) \quad \forall t \tag{5d}$$

$$\gamma_t^{C}(\xi)\leqslant \sum_{i\in I}K_i-\gamma_t(\xi) \quad \forall t \tag{5e}$$

$$0\leqslant \gamma_t(\xi)\leqslant \sum_{i\in I}K_i \quad \forall t \tag{5f}$$

$$\gamma_{t+1}(\xi)=\gamma_t(\xi)+\gamma_t^{C}(\xi)-\gamma_t^{D}(\xi) \quad \forall t \tag{5g}$$

$$\beta_t^{+}(\xi)\leqslant M_2\mu_t(\xi), \quad \beta_t^{-}(\xi)\leqslant M_2(1-\mu_t(\xi)) \quad \forall t \tag{5h}$$

$$\beta_t^{-}(\xi)\leqslant M_2\eta_t(\xi), \quad \gamma_t^{C}(\xi)\leqslant M_2(1-\eta_t(\xi)) \quad \forall t \tag{5i}$$

$$\gamma_t^{C}(\xi)\leqslant M_2\lambda_t(\xi), \quad \gamma_t^{D}(\xi)\leqslant M_2(1-\lambda_t(\xi)) \quad \forall t \tag{5j}$$

2.3 Settlement

$$\max \quad \sum_{t\in T}\left(P_t^{DA}\alpha_t + \mathbb{E}\left[P_t^{RT}(\xi)\beta_t^+(\xi) - P_t^{PN}\beta_t^-(\xi))\right]\right)$$

$$\begin{aligned}
\text{s.t.}\quad & R_{it}(\xi) - x_{it} = y_{it}^+(\xi) - y_{it}^-(\xi) + z_{it}^C(\xi) - z_{it}^D(\xi) \quad \forall i,t\\
& R_{it}(\xi) \geqslant y_{it}^+(\xi) \quad \forall i,t\\
& z_{it}^D(\xi) \leqslant z_{it}(\xi) \quad \forall i,t\\
& z_{it}^C(\xi) \leqslant K_i - z_{it}(\xi) \quad \forall i,t\\
& 0 \leqslant z_{it}(\xi) \leqslant K_i \quad \forall i,t\\
& y_{it}^+(\xi) \leqslant M_1\rho_{it}(\xi), \quad y_{it}^-(\xi) \leqslant M_1(1-\rho_{it}(\xi)) \quad \forall i,t\\
& y_{it}^-(\xi) \leqslant M_1\delta_{it}(\xi), \quad z_{it}^C(\xi) \leqslant M_1(1-\delta_{it}(\xi)) \quad \forall i,t\\
& z_{it}^C(\xi) \leqslant M_1\zeta_{it}(\xi), \quad z_{it}^D(\xi) \leqslant M_1(1-\zeta_{it}(\xi)) \quad \forall i,t\\
\\
& e_{it}^+(\xi) = y_{it}^+(\xi) - d_{it}^+(\xi)\\
& e_{it}^-(\xi) = y_{it}^-(\xi) - d_{it}^-(\xi)\\
& e_{it}^C(\xi) = z_{it}^C(\xi) - \widehat{d_{it}^C}(\xi) + \widetilde{d_{it}^C}(\xi)\\
& \widehat{d_{it}^C}(\xi) \leqslant M_1 q_{it}^3(\xi), \quad \widetilde{d_{it}^C}(\xi) \leqslant M_1(1-q_{it}^3(\xi))\\
& e_{it}^C(\xi) \leqslant K_i - z_{it}(\xi)\\
& e_{it}^D(\xi) = z_{it}^D(\xi) - \widehat{d_{it}^D}(\xi) + \widetilde{d_{it}^D}(\xi)\\
& \widehat{d_{it}^D}(\xi) \leqslant M_1 q_{it}^4(\xi), \quad \widetilde{d_{it}^D}(\xi) \leqslant M_1(1-q_{it}^4(\xi))\\
& e_{it}^D(\xi) \leqslant z_{it}(\xi)\\
& e_{it}^+(\xi) \leqslant M_1 q_{it}^5(\xi), \quad e_{it}^-(\xi) \leqslant M_1(1-q_{it}^5(\xi))\\
& e_{it}^-(\xi) \leqslant M_1 q_{it}^6(\xi), \quad e_{it}^C(\xi) \leqslant M_1(1-q_{it}^6(\xi))\\
& e_{it}^C(\xi) \leqslant M_1 q_{it}^6(\xi), \quad e_{it}^D(\xi) \leqslant M_1(1-q_{it}^6(\xi))\\
\\
& z_{i,t+1}(\xi) = z_{it}(\xi) + e_{it}^C(\xi) - e_{it}^D(\xi) \quad \forall i,t\\
& \alpha_t = \sum_{i\in I} x_{it}, \quad \beta_t^+(\xi) = \sum_{i\in I} e_{it}^+(\xi), \quad \beta_t^-(\xi) = \sum_{i\in I} e_{it}^-(\xi)\\
& \gamma_t(\xi) = \sum_{i\in I} z_{it}(\xi), \quad \gamma_t^C(\xi) = \sum_{i\in I} e_{it}^C(\xi), \quad \gamma_t^D(\xi) = \sum_{i\in I} e_{it}^D(\xi)\\
\\
& \sum_{i\in I} R_{it}(\xi) - \alpha_t = \beta_t^+(\xi) - \beta_t^-(\xi) + \gamma_t^C(\xi) - \gamma_t^D(\xi) \quad \forall t\\
& \sum_{i\in I} R_{it}(\xi) \geqslant \beta_t^+(\xi) \quad \forall t\\
& \gamma_t^D(\xi) \leqslant \gamma_t(\xi) \quad \forall t\\
& \gamma_t^C(\xi) \leqslant \sum_{i\in I} K_i - \gamma_t(\xi) \quad \forall t\\
& 0 \leqslant \gamma_t(\xi) \leqslant \sum_{i\in I} K_i \quad \forall t\\
& \gamma_{t+1}(\xi) = \gamma_t(\xi) + \gamma_t^C(\xi) - \gamma_t^D(\xi) \quad \forall t\\
& \beta_t^+(\xi) \leqslant M_2\mu_t(\xi), \quad \beta_t^-(\xi) \leqslant M_2(1-\mu_t(\xi)) \quad \forall t\\
& \beta_t^-(\xi) \leqslant M_2\eta_t(\xi), \quad \gamma_t^C(\xi) \leqslant M_2(1-\eta_t(\xi)) \quad \forall t\\
& \gamma_t^C(\xi) \leqslant M_2\lambda_t(\xi), \quad \gamma_t^D(\xi) \leqslant M_2(1-\lambda_t(\xi)) \quad \forall t\\
\\
& \sum_{i\in I} \widehat{d_{it}^C}(\xi) \leqslant \sum_{i\in I} y_{it}^-(\xi)\\
& \sum_{i\in I} \widetilde{d_{it}^D}(\xi) \leqslant \sum_{i\in I} y_{it}^-(\xi)\\
& \left(d_{it}^+(\xi) - \sum_{i\in I} y_{it}^-(\xi)\right) - (K_i - z_{it}(\xi)) \leqslant M_1(1-q_{it}^6(\xi)) - \epsilon\\
& (K_i - z_{it}(\xi)) - e_{it}^C(\xi) \leqslant M_1 q_{it}^6(\xi)\\
& (K_i - z_{it}(\xi)) - \left(d_{it}^+(\xi) - \sum_{i\in I} y_{it}^-(\xi)\right) \leqslant M_1(1-q_{it}^7(\xi)) - \epsilon\\
& \left(e_{it}^C(\xi)\right) - \left(d_{it}^+(\xi) + z_{it}^c(\xi)\right) \leqslant M_1 q_{it}^7(\xi)
\end{aligned}$$

3 With Individual Storage

3.1 RT Storage Dispatching: for each i

$$\max \quad \sum_{t\in T}\left(P_t^{DA}x_{it}+\mathbb{E}\left[P_t^{RT}(\xi)y_{it}^{+}(\xi)-P_t^{PN}y_{it}^{-}(\xi)\right]\right) \tag{7a}$$

$$\text{s.t.} \quad R_{it}(\xi)-x_{it}=y_{it}^{+}(\xi)-y_{it}^{-}(\xi)+z_{it}^{C}(\xi)-z_{it}^{D}(\xi) \quad \forall i,t \tag{7b}$$

$$R_{it}(\xi)\geqslant y_{it}^{+}(\xi) \quad \forall i,t \tag{7c}$$

$$z_{i,t+1}(\xi)=z_{it}(\xi)+z_{it}^{C}(\xi)-z_{it}^{D}(\xi) \quad \forall i,t \tag{7d}$$

$$z_{it}^{D}(\xi)\leqslant z_{it}(\xi) \quad \forall i,t \tag{7e}$$

$$z_{it}^{C}(\xi)\leqslant K_i-z_{it}(\xi) \quad \forall i,t \tag{7f}$$

$$0\leqslant z_{it}(\xi)\leqslant K_i \quad \forall i,t \tag{7g}$$

$$y_{it}^{+}(\xi)\leqslant M_1\rho_{it}(\xi), \quad y_{it}^{-}(\xi)\leqslant M_1(1-\rho_{it}(\xi)) \quad \forall i,t \tag{7h}$$

$$y_{it}^{-}(\xi)\leqslant M_1\delta_{it}(\xi), \quad z_{it}^{C}(\xi)\leqslant M_1(1-\delta_{it}(\xi)) \quad \forall i,t \tag{7i}$$

$$z_{it}^{C}(\xi)\leqslant M_1\zeta_{it}(\xi), \quad z_{it}^{D}(\xi)\leqslant M_1(1-\zeta_{it}(\xi)) \quad \forall i,t \tag{7j}$$

3.2 RT Storage Dispatching with aggregation

$$
\begin{aligned}
\max \quad & \sum_{t\in T}\left(P_t^{DA}\alpha_t + \mathbb{E}\left[P_t^{RT}(\xi)\beta_t^+(\xi) - P_t^{PN}\beta_{it}^-(\xi)\right]\right) \\
\text{s.t.} \quad & R_{it}(\xi) - x_{it} = y_{it}^+(\xi) - y_{it}^-(\xi) + z_{it}^C(\xi) - z_{it}^D(\xi), \quad R_{it}(\xi) \geqslant y_{it}^+(\xi) \\
& y_{it}^+(\xi) \leqslant M_1\rho_{it}(\xi), \quad y_{it}^-(\xi) \leqslant M_1(1-\rho_{it}(\xi)) \\
& y_{it}^-(\xi) \leqslant M_1\delta_{it}(\xi), \quad z_{it}^C(\xi) \leqslant M_1(1-\delta_{it}(\xi)) \\
& z_{it}^C(\xi) \leqslant M_1\zeta_{it}(\xi), \quad z_{it}^D(\xi) \leqslant M_1(1-\zeta_{it}(\xi)) \\
& z_{it}^D(\xi) \leqslant z_{it}(\xi), \quad z_{it}^C(\xi) \leqslant K_i - z_{it}(\xi), \quad 0 \leqslant z_{it}(\xi) \leqslant K_i
\end{aligned}
$$

$$
\begin{aligned}
& e_{it}^+(\xi) = y_{it}^+(\xi) - \sum_{j\in I} d_{ijt}^+(\xi), \quad e_{it}^-(\xi) = y_{it}^-(\xi) - \sum_{j\in I} d_{ijt}^-(\xi) \\
& e_{it}^C(\xi) = z_{it}^C(\xi) - \sum_{j\in I}\widehat{d_{ijt}^C}(\xi) + \sum_{j\in I}\widetilde{d_{ijt}^C}(\xi), \quad e_{it}^D(\xi) = z_{it}^D(\xi) - \sum_{j\in I}\widehat{d_{ijt}^D}(\xi) + \sum_{j\in I}\widetilde{d_{ijt}^D}(\xi) \\
& e_{it}^C(\xi) \leqslant K_i - z_{it}(\xi), \quad e_{it}^D(\xi) \leqslant z_{it}(\xi), \quad e_{it}^D(\xi) \geqslant min\{y_{it}^-(\xi), z_{it}(\xi)\}, \quad z_{i,t+1}(\xi) = z_{it}(\xi) + e_{it}^C(\xi) - e_{it}^D(\xi)
\end{aligned}
$$

$$
\begin{aligned}
& y_{it}^+(\xi) \geqslant \sum_{j\in I} d_{ijt}^+(\xi), \quad y_{it}^-(\xi) \geqslant \sum_{j\in I} d_{ijt}^-(\xi), \quad z_{it}^C(\xi) \geqslant \sum_{j\in I}\widehat{d_{ijt}^C}(\xi), \quad z_{it}^D(\xi) \geqslant \sum_{j\in I}\widehat{d_{ijt}^D}(\xi) \\
& \sum_{i\in I} y_{it}^-(\xi) \geqslant \sum_{j\in I}\widehat{d_{jit}^C}(\xi), \quad \sum_{i\in I} y_{it}^-(\xi) \geqslant \sum_{j\in I}\widetilde{d_{jit}^D}(\xi) \\
& \sum_{j\in I} d_{ijt}^+(\xi) - \sum_{j\in I, j\neq i} d_{jit}^+(\xi) = d_{iit}^+(\xi) \\
& d_{iit}^+(\xi) \geqslant \widetilde{d_{iit}^C}(\xi) + \widehat{d_{iit}^D}(\xi) \\
& \widetilde{d_{iit}^C}(\xi) \geqslant min\{d_{iit}^+(\xi) - \widehat{d_{iit}^D}(\xi), K_i - z_{it}(\xi) - z_{it}^C(\xi)\} \\
& d_{jit}^-(\xi) \geqslant d_{jit}^+(\xi) + \widehat{d_{jit}^C}(\xi) + \widetilde{d_{jit}^D}(\xi) \quad \forall j \in I, j \neq i
\end{aligned}
$$

$$
\begin{aligned}
& \sum_{j\in I}\widehat{d_{ijt}^C}(\xi) \leqslant M_1 q_{it}^1(\xi), \quad \widetilde{d_{iit}^C}(\xi) \leqslant M_1(1-q_{it}^1(\xi)) \\
& \widehat{d_{iit}^D}(\xi) \leqslant M_1 q_{it}^2(\xi), \quad \sum_{j\in I}\widetilde{d_{ijt}^D}(\xi) \leqslant M_1(1-q_{it}^2(\xi)) \\
& e_{it}^+(\xi) \leqslant M_1 q_{it}^3(\xi), \quad e_{it}^-(\xi) \leqslant M_1(1-q_{it}^3(\xi)) \\
& e_{it}^-(\xi) \leqslant M_1 q_{it}^4(\xi), \quad e_{it}^C(\xi) \leqslant M_1(1-q_{it}^4(\xi)) \\
& e_{it}^C(\xi) \leqslant M_1 q_{it}^5(\xi), \quad e_{it}^D(\xi) \leqslant M_1(1-q_{it}^5(\xi))
\end{aligned}
$$

$$
\begin{aligned}
& \alpha_t = \sum_{i\in I} x_{it}, \quad \beta_t^+(\xi) = \sum_{i\in I} e_{it}^+(\xi), \quad \beta_t^-(\xi) = \sum_{i\in I} e_{it}^-(\xi), \quad \gamma_t^C(\xi) = \sum_{i\in I} e_{it}^C(\xi), \quad \gamma_t^D(\xi) = \sum_{i\in I} e_{it}^D(\xi) \\
& \sum_{i\in I} R_{it}(\xi) - \alpha_t = \beta_t^+(\xi) - \beta_t^-(\xi) + \gamma_t^C(\xi) - \gamma_t^D(\xi), \quad \sum_{i\in I} R_{it}(\xi) \geqslant \beta_t^+(\xi) \\
& \beta_t^+(\xi) \leqslant M_2\mu_t(\xi), \quad \beta_t^-(\xi) \leqslant M_2(1-\mu_t(\xi)) \\
& \beta_t^-(\xi) \leqslant M_2\eta_t(\xi), \quad \gamma_t^C(\xi) \leqslant M_2(1-\eta_t(\xi))
\end{aligned}
$$

3.3 RT Storage Dispatching with aggregation (2)

$$
\begin{aligned}
\max \quad & \sum_{t\in T}\left(P_t^{DA}\alpha_t + \mathbb{E}\left[P_t^{RT}(\xi)\beta_t^+(\xi) - P_t^{PN}\beta_{it}^-(\xi)\right]\right)\\
\text{s.t.} \quad & R_{it}(\xi) - x_{it} = y_{it}^+(\xi) - y_{it}^-(\xi) + z_{it}^C(\xi) - z_{it}^D(\xi), \quad R_{it}(\xi) \geqslant y_{it}^+(\xi)\\
& y_{it}^+(\xi) \leqslant M_1\rho_{it}(\xi), \quad y_{it}^-(\xi) \leqslant M_1(1-\rho_{it}(\xi))\\
& y_{it}^-(\xi) \leqslant M_1\delta_{it}(\xi), \quad z_{it}^C(\xi) \leqslant M_1(1-\delta_{it}(\xi))\\
& z_{it}^C(\xi) \leqslant M_1\zeta_{it}(\xi), \quad z_{it}^D(\xi) \leqslant M_1(1-\zeta_{it}(\xi))\\
& z_{it}^D(\xi) \leqslant z_{it}(\xi), \quad z_{it}^C(\xi) \leqslant K_i - z_{it}(\xi), \quad 0 \leqslant z_{it}(\xi) \leqslant K_i
\end{aligned}
$$

$$
\begin{aligned}
& e_{it}^+(\xi) = y_{it}^+(\xi) - \sum_{j\in I} d_{ijt}^+(\xi), \quad e_{it}^-(\xi) = y_{it}^-(\xi) - d_{it}^-(\xi)\\
& e_{it}^C(\xi) = z_{it}^C(\xi) - \sum_{j\in I}\widehat{d_{ijt}^C}(\xi) + \widetilde{d_{it}^C}(\xi), \quad e_{it}^D(\xi) = z_{it}^D(\xi) - \widehat{d_{it}^D}(\xi) + \sum_{j\in I}\widetilde{d_{ijt}^D}(\xi)\\
& e_{it}^C(\xi) \leqslant K_i - z_{it}(\xi), \quad e_{it}^D(\xi) \leqslant z_{it}(\xi), \quad z_{i,t+1}(\xi) = z_{it}(\xi) + e_{it}^C(\xi) - e_{it}^D(\xi)
\end{aligned}
$$

$$
\begin{aligned}
& y_{it}^+(\xi) \geqslant \sum_{j\in I} d_{ijt}^+(\xi), \quad y_{it}^-(\xi) \geqslant d_{it}^-(\xi), \quad z_{it}^C(\xi) \geqslant \sum_{j\in I}\widehat{d_{ijt}^C}(\xi), \quad z_{it}^D(\xi) \geqslant \widehat{d_{it}^D}(\xi)\\
& \sum_{i\in I} y_{it}^-(\xi) \geqslant \sum_{j\in I}\widehat{d_{ijt}^C}(\xi), \quad \sum_{i\in I} y_{it}^-(\xi) \geqslant \sum_{j\in I}\widetilde{d_{ijt}^D}(\xi)??\\
& y_{it}^-(\xi) \geqslant d_{ijt}^+(\xi) + \widehat{d_{ijt}^C}(\xi) + \widetilde{d_{ijt}^D}(\xi) \quad (\forall j \in I, j \neq i)\\
& y_{it}^-(\xi) \geqslant \widehat{d_{iit}^C}(\xi) + \widetilde{d_{iit}^D}(\xi)\\
& e_{it}^D(\xi) \geqslant min\{y_{it}^-(\xi), z_{it}(\xi)\}\\
& \widetilde{d_{it}^C}(\xi) \geqslant min\{d_{iit}^+(\xi) - \widehat{d_{it}^D}(\xi), K_i - z_{it}(\xi) - z_{it}^C(\xi)\}??\\
& \sum_{j\in I} d_{ijt}^+(\xi) - \sum_{j\in I, j\neq i} d_{jit}^+(\xi) = d_{iit}^+(\xi)
\end{aligned}
$$

$$
\begin{aligned}
& \sum_{j\in I}\widehat{d_{ijt}^C}(\xi) \leqslant M_1 q_{it}^1(\xi), \quad \widetilde{d_{it}^C}(\xi) \leqslant M_1(1-q_{it}^1(\xi))\\
& \widehat{d_{it}^D}(\xi) \leqslant M_1 q_{it}^2(\xi), \quad \sum_{j\in I}\widetilde{d_{ijt}^D}(\xi) \leqslant M_1(1-q_{it}^2(\xi))\\
& e_{it}^+(\xi) \leqslant M_1 q_{it}^3(\xi), \quad e_{it}^-(\xi) \leqslant M_1(1-q_{it}^3(\xi))\\
& e_{it}^-(\xi) \leqslant M_1 q_{it}^4(\xi), \quad e_{it}^C(\xi) \leqslant M_1(1-q_{it}^4(\xi))\\
& e_{it}^C(\xi) \leqslant M_1 q_{it}^5(\xi), \quad e_{it}^D(\xi) \leqslant M_1(1-q_{it}^5(\xi))
\end{aligned}
$$

$$
\begin{aligned}
& \alpha_t = \sum_{i\in I} x_{it}, \quad \beta_t^+(\xi) = \sum_{i\in I} e_{it}^+(\xi), \quad \beta_t^-(\xi) = \sum_{i\in I} e_{it}^-(\xi), \quad \gamma_t^C(\xi) = \sum_{i\in I} e_{it}^C(\xi), \quad \gamma_t^D(\xi) = \sum_{i\in I} e_{it}^D(\xi)\\
& \sum_{i\in I} R_{it}(\xi) - \alpha_t = \beta_t^+(\xi) - \beta_t^-(\xi) + \gamma_t^C(\xi) - \gamma_t^D(\xi), \quad \sum_{i\in I} R_{it}(\xi) \geqslant \beta_t^+(\xi)\\
& \beta_t^+(\xi) \leqslant M_2\mu_t(\xi), \quad \beta_t^-(\xi) \leqslant M_2(1-\mu_t(\xi))\\
& \beta_t^-(\xi) \leqslant M_2\eta_t(\xi), \quad \gamma_t^C(\xi) \leqslant M_2(1-\eta_t(\xi))
\end{aligned}
$$

3.4 DA + RT Storage Dispatching: for each i

$$\max \quad \sum_{t\in T}\left(P_t^{DA}x_{it}+\mathbb{E}\left[P_t^{RT}(\xi)y_{it}^{+}(\xi)-P_t^{PN}y_{it}^{-}(\xi)\right]\right) \tag{8a}$$

$$\text{s.t.} \quad x_{it}+zd_{it}^{DA}-zc_{it}^{DA} \leqslant / = \widetilde{R_{it}} \tag{8b}$$

$$zc_{it}^{DA} \leqslant K_i - z_{it}(\xi), \quad zd_{it}^{DA} \leqslant z_{it}(\xi) \tag{8c}$$

$$zc_{it}^{DA} \leqslant M_1\mu_{it}, \quad zd_{it}^{DA} \leqslant M_1(1-\mu_{it}) \tag{8d}$$

$$-- \tag{8e}$$

$$R_{it}(\xi)-x_{it}-zc_{it}^{DA}+zd_{it}^{DA}=y_{it}^{+}(\xi)-y_{it}^{-}(\xi)+zc_{it}^{RT}(\xi)-zd_{it}^{RT}(\xi) \tag{8f}$$

$$R_{it}(\xi) \geqslant y_{it}^{+}(\xi) \tag{8g}$$

$$zd_{it}^{RT}(\xi) \leqslant z_{it}(\xi)-zd_{it}^{DA}(\xi)+zc_{it}^{DA}(\xi) \tag{8h}$$

$$zc_{it}^{RT}(\xi) \leqslant K_i - z_{it}(\xi)+zd_{it}^{DA}(\xi)-zc_{it}^{DA}(\xi) \tag{8i}$$

$$0 \leqslant z_{it}(\xi) \leqslant K_i \tag{8j}$$

$$z_{i,t+1}(\xi)=z_{it}(\xi)+zc_{it}^{DA}-zd_{it}^{DA}+zc_{it}^{RT}(\xi)-zd_{it}^{RT}(\xi) \tag{8k}$$

$$y_{it}^{+}(\xi) \leqslant M_1\rho_{it}(\xi), \quad y_{it}^{-}(\xi) \leqslant M_1(1-\rho_{it}(\xi)) \tag{8l}$$

$$y_{it}^{-}(\xi) \leqslant M_1\delta_{it}(\xi), \quad zc_{it}^{RT}(\xi) \leqslant M_1(1-\delta_{it}(\xi)) \tag{8m}$$

$$zc_{it}^{RT}(\xi) \leqslant M_1\zeta_{it}(\xi), \quad zd_{it}^{RT}(\xi) \leqslant M_1(1-\zeta_{it}(\xi)) \tag{8n}$$

3.5 DA + RT Storage Dispatching with aggregation