DER Models

Seohyun Jang

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1 Without Storage

1.1 Disaggregation

$$max \quad \sum_{t \in T} \left(P_t^{DA} x_{it} + \mathbb{E}\left[P_t^{RT}(\xi) y_{it}^+(\xi) - P_t^{PN} y_{it}^-(\xi) \right] \right) \tag{1a}$$

$$s.t. \quad R_{it}(\xi) - x_{it} = y_{it}^+(\xi) - y_{it}^-(\xi) \quad \forall t \in T \tag{1b}$$

$$R_{it}(\xi) \geqslant y_{it}^+(\xi) \quad \forall t \in T \tag{1c}$$

$$y_{it}^+(\xi) \leqslant M z_{it}(\xi), \quad y_{it}^-(\xi) \leqslant M(1 - z_{it}(\xi)) \quad \forall t \in T \tag{1d}$$

$$x_{it}^{DA} \geqslant 0, y_{it}^+(\xi) \geqslant 0, y_{it}^-(\xi) \geqslant 0, z_{it}(\xi) \in \{0,1\} \quad \forall t \in T \tag{1e}$$

1.2 Aggregation

$$max \quad \sum_{t \in T} \left(P_t^{DA} \alpha_t + \mathbb{E}\left[P_t^{RT}(\xi) \beta_t^+(\xi) - P_t^{PN} \beta_t^-(\xi) \right] \right) \tag{2a}$$

$$s.t. \quad \sum_{i \in I} R_{it}(\xi) - \alpha_t = \beta_t^+(\xi) - \beta_t^-(\xi) \quad \forall t \in T \tag{2b}$$

$$\sum_{i \in I} R_{it}(\xi) \geqslant \beta_t^+(\xi) \quad \forall t \in T \tag{2c}$$

$$\beta_t^+(\xi) \leqslant M z_t(\xi), \quad \beta_t^-(\xi) \leqslant M(1 - z_t(\xi)) \quad \forall t \in T \tag{2d}$$

$$\alpha_t^{DA} \geqslant 0, \beta_t^+(\xi) \geqslant 0, \beta_t^-(\xi) \geqslant 0, z_t(\xi) \in \{0,1\} \quad \forall t \in T \tag{2e}$$

1.3 Settlement

$$max \quad \sum_{t \in T} \left(P_t^{DA} \alpha_t + \mathbb{E}\left[P_t^{RT}(\xi) \beta_t^+(\xi) - P_t^{PN} \beta_t^-(\xi) \right] \right) \tag{3a}$$

$$s.t. \quad \sum_{i \in I} R_{it}(\xi) - \alpha_t^{DA} = \beta_t^+(\xi) - \beta_t^-(\xi) \quad \forall t \in T \tag{3b}$$

$$\sum_{i \in I} R_{it}(\xi) \geqslant \beta_t^+(\xi) \quad \forall t \in T \tag{3c}$$

$$\beta_t^+(\xi) \leqslant M z_t(\xi), \quad \beta_t^-(\xi) \leqslant M(1 - z_t(\xi)) \quad \forall t \in T \tag{3d}$$

$$\alpha_t = \sum_{i \in I} x_{it}(\xi), \quad \beta_t^+(\xi) = \sum_{i \in I} e_{it}^+(\xi), \quad \beta_t^-(\xi) = \sum_{i \in I} e_{it}^-(\xi) \quad \forall t \in T \tag{3e}$$

$$R_{it}(\xi) - x_{it}(\xi) = y_{it}^+(\xi) - y_{it}^-(\xi) \quad \forall t \in T \tag{3f}$$

$$R_{it}(\xi) \geqslant y_{it}^+(\xi) \quad \forall t \in T \tag{3g}$$

$$y_{it}^+(\xi) \leqslant M z_{it}(\xi), \quad y_{it}^-(\xi) \leqslant M(1 - z_{it}(\xi)) \quad \forall t \in T \tag{3h}$$

$$\sum_{j \in I, j \neq i} d_{ijt}(\xi) \leqslant y_{it}^+(\xi), \quad \sum_{j \in I, j \neq i} d_{jit}(\xi) \leqslant y_{it}^-(\xi) \quad \forall t \in T \tag{3i}$$

$$d_{iit}(\xi) = 0 \quad \forall t \in T \tag{3j}$$

$$e_{it}^+(\xi) = y_{it}^+(\xi) - \sum_{j \in I, j \neq i} d_{ijt}(\xi) \quad \forall t \in T \tag{3k}$$

$$e_{it}^-(\xi) = y_{it}^-(\xi) - \sum_{j \in I, j \neq i} d_{jit}(\xi) \quad \forall t \in T \tag{3l}$$

2 With Storage

2.1 Disaggregation

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

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

$$R_{it}(\xi) \geqslant y_{it}^+(\xi) \tag{4c}$$

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

$$z_{it}^D(\xi) \leqslant z_{it}(\xi), \quad z_{it}^C(\xi) \leqslant K_i - z_{it}(\xi), \quad 0 \leqslant z_{it}(\xi) \leqslant K_i \tag{4e}$$

$$y_{it}^+(\xi) \leqslant M_1 \phi_{it}^1(\xi), \quad y_{it}^-(\xi) \leqslant M_1(1 - \phi_{it}^1(\xi)) \tag{4f}$$

$$y_{it}^-(\xi) \leqslant M_1 \phi_{it}^2(\xi), \quad z_{it}^C(\xi) \leqslant M_1(1 - \phi_{it}^2(\xi)) \tag{4g}$$

$$z_{it}^C(\xi) \leqslant M_1 \phi_{it}^3(\xi), \quad z_{it}^D(\xi) \leqslant M_1(1 - \phi_{it}^3(\xi)) \tag{4h}$$

2.2 Aggregation with BTM storage control

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

$$\tag{5b}$$

$$\text{s.t.} \quad R_{it}(\xi) - x_{it} = y_{it}^+(\xi) - y_{it}^-(\xi) + z_{it}^C(\xi) - z_{it}^D(\xi) \tag{5c}$$

$$R_{it}(\xi) \geqslant y_{it}^+(\xi) \tag{5d}$$

$$z_{i,t+1}(\xi) = z_{it}(\xi) + z_{it}^C(\xi) - z_{it}^D(\xi) \tag{5e}$$

$$z_{it}^D(\xi) \leqslant z_{it}(\xi), \quad z_{it}^C(\xi) \leqslant K_i - z_{it}(\xi), \quad 0 \leqslant z_{it}(\xi) \leqslant K_i \tag{5f}$$

$$e_{it}^+(\xi) = y_{it}^+(\xi) - \sum_{j \in I} d_{ijt}(\xi), \quad e_{it}^-(\xi) = y_{it}^-(\xi) - \sum_{j \in I} d_{jit}(\xi) \tag{5g}$$

$$d_{iit}(\xi) = 0 \tag{5h}$$

$$y_{it}^+(\xi) \leqslant M_1 \phi_{it}^1(\xi), \quad y_{it}^-(\xi) \leqslant M_1(1 - \phi_{it}^1(\xi)) \tag{5i}$$

$$y_{it}^-(\xi) \leqslant M_1 \phi_{it}^2(\xi), \quad z_{it}^C(\xi) \leqslant M_1(1 - \phi_{it}^2(\xi)) \tag{5j}$$

$$z_{it}^C(\xi) \leqslant M_1 \phi_{it}^3(\xi), \quad z_{it}^D(\xi) \leqslant M_1(1 - \phi_{it}^3(\xi)) \tag{5k}$$

$$\sum_{i \in I} e_{it}^+(\xi) \leqslant M_2 \phi_{it}^4(\xi), \quad \sum_{i \in I} e_{it}^-(\xi) \leqslant M_2(1 - \phi_{it}^4(\xi)) \tag{5l}$$

2.3 Aggregation with direct control over storage

$$\max \quad \sum_{t \in T} \left(P_t^{DA} \alpha_t + \mathbb{E}\left[P_t^{RT}(\xi) \beta_t^+(\xi) - P_t^{PN} \beta_t^-(\xi) \right] \right) \tag{6a}$$

$$\text{s.t.} \quad \sum_{i \in I} R_{it}(\xi) - \alpha_t = \beta_t^+(\xi) - \beta_t^-(\xi) + \gamma_t^C(\xi) - \gamma_t^D(\xi) \quad \forall t \tag{6b}$$

$$\sum_{i \in I} R_{it}(\xi) \geqslant \beta_t^+(\xi) \tag{6c}$$

$$\gamma_t^D(\xi) \leqslant \gamma_t(\xi), \quad \gamma_t^C(\xi) \leqslant \sum_{i \in I} K_i - \gamma_t(\xi), \quad 0 \leqslant \gamma_t(\xi) \leqslant \sum_{i \in I} K_i \quad \forall t \tag{6d}$$

$$\gamma_{t+1}(\xi) = \gamma_t(\xi) + \gamma_t^C(\xi) - \gamma_t^D(\xi) \quad \forall t \tag{6e}$$

$$\beta_t^+(\xi) \leqslant M_2 \mu_t(\xi), \quad \beta_t^-(\xi) \leqslant M_2(1 - \mu_t(\xi)) \quad \forall t \tag{6f}$$

$$\beta_t^-(\xi) \leqslant M_2 \eta_t(\xi), \quad \gamma_t^C(\xi) \leqslant M_2(1 - \eta_t(\xi)) \quad \forall t \tag{6g}$$

$$\gamma_t^C(\xi) \leqslant M_2 \lambda_t(\xi), \quad \gamma_t^D(\xi) \leqslant M_2(1 - \lambda_t(\xi)) \quad \forall t \tag{6h}$$