

1. Descriptions of Day-ahead and Real-time Energy Dispatch Problems

We firstly give the detailed form of the day-ahead operation problem. Let $x_{1,D}, x_{2,D}$ denote the power generation of DG1 and DG2, where $\mathbf{x}_D = [x_{1,D}, x_{2,D}]$. Let $\bar{x}_i, \forall i \in \{1, 2\}$ be the power capacity of those two DGs. The day-ahead operation problem is given by

$$\min_{\{x_{1,d,\tau}\}_{\tau=0}^T, \{x_{2,d,\tau}\}_{\tau=0}^T} \sum_{\tau=0}^T \sum_{i=1}^2 b_i \cdot x_{i,d,\tau} \quad (1a)$$

$$\text{s.t.} \quad 0 \leq x_{i,d,\tau} \leq \bar{x}_{i,d,\tau}, \forall i \in \{1, 2\}, \forall \tau = 0, \dots, T \quad (1b)$$

$$-r_i \leq x_{i,d,\tau+1} - x_{i,d,\tau} \leq r_i, \forall i \in \{1, 2\}, \forall \tau = 0, \dots, T-1 \quad (1c)$$

$$x_{1,d,\tau} + x_{2,d,\tau} + \tilde{y}_{d,\tau}^* = l_{d,\tau}, \forall \tau = 0, \dots, T, \quad (1d)$$

where (1b) gives the constraint of maximum output power of DGs, (1c) gives the ramping constraints of DGs and (1d) gives the power balance constraint.

For the real-time operation problem, let $\tilde{z}_{i,d,\tau}^U, \forall i \in 1, 2$ denote the block of up-regulation power, and $\tilde{z}_{1,d,\tau}^D$ denote the block of down-regulation power, where $\tilde{\mathbf{z}}_{d,\tau} = [\tilde{z}_{1,d,\tau}^U, \tilde{z}_{2,d,\tau}^U, \tilde{z}_{1,d,\tau}^D]$. Let c_i^U, c_i^D denote the up- and down- unit regulation costs. With the objective of minimizing the operation cost, the real-time operation problem is defined as

$$\{\min_{\tilde{\mathbf{z}}_{d,\tau}} -c_1^D \tilde{z}_{1,d,\tau}^D + \sum_{i=1}^2 c_i^U \tilde{z}_{i,d,\tau}^U \quad (2a)$$

$$\text{s.t.} \quad 0 \leq \tilde{z}_{1,d,\tau}^D \leq \bar{z}_1^D \quad (2b)$$

$$0 \leq \tilde{z}_{i,d,\tau}^U \leq \bar{z}_i^U, \forall i \in \{1, 2\} \quad (2c)$$

$$-z_{1,d,\tau}^D + \sum_{i=1}^2 \tilde{z}_{i,d,\tau}^U + y_{d,\tau} - \tilde{y}_{d,\tau}^* = 0, \forall \tau = 0, \dots, T, \quad (2d)$$

where (2b) and (2c) are the constraints regarding the output limits of regulation blocks. Eq. (2d) ensures that the deviation is settled by the outputs of regulation blocks. The values of parameters in (1) and (2) are shown in Table 1, and Table 2.

Table 1: Costs and technical data of day-ahead operation

	\bar{x}_i (kW)	b_i (\$/kW)	r_i (kW)
DG_1	70	30	50
DG_2	70	40	50

Table 2: Regulation costs and technical data of real-time operation

c_1^D /\$	c_1^U /\$	c_2^U /\$	\bar{z}_1^D /kW	\bar{z}_1^U /kW	\bar{z}_2^U /kW
20	100	200	30	10	30