i) 对于省间市场出清模型，将其原变量和对偶变量表示为：

$$\min\sum_{t=1}^{T}(\sum_{i=1}^{I}\sum_{k=1}^{K}\alpha_{i,k}^{2}P_{i,t,k}^{2}-\sum_{j=1}^{J}\sum_{k=1}^{K}\beta_{j,k}^{2}D_{j,t,k}^{2})$$

$$P_{r,t}=\sum_{i\in X_r}\sum_{k=1}^{K}P_{i,t,k}^{2}-\sum_{j\in Y_r}\sum_{k=1}^{K}D_{j,t,k}^{2}:\pi_{r,t}^{2}$$

$$-\sum_{l\in Z_r}\overline{P}_{l}^{Ex}\le P_{r,t}\le\sum_{l\in Z_r}\overline{P}_{l}^{Ex}:\tau_{r,t}^{,\min},\tau_{r,t}^{x,\max}$$

$$0\le P_{i,t,k}^{2}\le\overline{P}_{i,k}^{2}:\zeta_{i,t,k}^{G2,\min},\zeta_{i,t,k}^{G2,\max}$$

$$0\le D_{j,t,k}^{2}\le\overline{D}_{j,k}^{2}:\zeta_{i,t,k}^{D2,\min},\zeta_{i,t,k}^{D2,\max}$$

上述问题的形式为线性规划问题，其拉格朗日函数可以表示为：

$$L=\sum_{t\ 1}^{T}(\sum_{i=1}^{I}\sum_{k\ 1}^{K}\alpha_{i,k}^{2}P_{i,t,k}^{2}-\sum_{j\ 1}^{J}\sum_{k\ 1}^{K}\beta_{j,k}^{2}D_{j,t,k}^{2})$$

$$+\sum_{t=1}^{T}\sum_{r=1}^{R}\pi_{r,t}^{2}(P_{r,t}-\sum_{i\in X_r}\sum_{k=1}^{K}P_{i,t,k}^{2}+\sum_{j\in Y_r}\sum_{k=1}^{K}D_{j,t,k}^{2})$$

$$-\sum_{t=1}^{T}\sum_{r}\tau_{r,t}^{Ex,\min}(P_{r,t}+\sum_{l\in Z_r}\overline{P}_{l}^{Ex})$$

$$+\sum_{t=1}^{T}\sum_{r}\tau_{r,t}^{Ex,\max}(P_{r,t}-\sum_{l\in Z_r}\overline{P}_{l}^{Ex})$$

$$+\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{k=1}^{K}\zeta_{i,t,k}^{G2,\max}(P_{i,t,k}^{2}-\overline{P}_{i,k}^{2})$$

$$+\sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{k=1}^{K}\zeta_{j,t,k}^{D2,\max}(D_{j,t,k}^{2}-\overline{D}_{j,k}^{2})$$

$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{k=1}^{K}\zeta_{i,t,k}^{G2,\min}P_{i,t,k}^{2}$$

$$-\sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{k=1}^{K}\zeta_{j,t,k}^{D2,\min}D_{j,t,k}^{2}$$

其最优性条件可以表示为：

（原始可行）：

$$P_{r,t}=\sum_{i\in X_r}\sum_{k=1}^{K}P_{i,t,k}^{2}-\sum_{j\in Y_r}\sum_{k=1}^{K}D_{j,t,k}^{2}$$

$$-\sum_{l\in Z_r}\overline{P}_{l}^{Ex}\le P_{r,t}\le\sum_{l\in Z_r}\overline{P}_{l}^{Ex}$$

$$0\le P_{i,t,k}^{2}\le\overline{P}_{i,k}^{2}$$

$$0\le D_{j,t,k}^{2}\le\overline{D}_{j,k}^{2}$$

（对偶可行）：

$$\alpha_{i,k}^{2}-\pi_{r,t}^{2}+\zeta_{i,t,k}^{G2,\max}-\zeta_{i,t,k}^{G2,\min}=0$$

$$-\beta_{j,k}^{2}+\pi_{r,t}^{2}+\zeta_{j,t,k}^{D2,\max}-\zeta_{j,t,k}^{D2,\min}=0$$

$$\pi_{r,t}^{2}-\tau_{r,t}^{Ex,\min}+\tau_{r,t}^{Ex,\max}=0$$

$$\tau_{r,t}^{Ex,\min},\tau_{r,t}^{Ex,\max}\geq 0$$

$$\zeta_{i,t,k}^{G2,\max},\zeta_{i,t,k}^{G2,\min}\geq 0$$

$$\zeta_{j,t,k}^{D2,\max},\zeta_{j,t,k}^{D2,\min}\geq 0$$

（强对偶条件）：

$$\sum_{t=1}^{T}(\sum_{i=1}^{I}\sum_{k=1}^{K}\alpha_{i,k}^{2}P_{i,t,k}^{2}-\sum_{j=1}^{J}\sum_{k=1}^{K}\beta_{j,k}^{2}D_{j,t,k}^{2})-\sum_{t=1}^{T}\sum_{r}\tau_{r}^{Ex,\min}\sum_{l\in Z_r}\overline{P}_{l,t}^{Ex}-\sum_{t=1}^{T}\sum_{r}\tau_{r,t}^{Ex,\max}\sum_{l\in Z_r}\overline{P}_{l,t}^{Ex}$$

$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{k=1}^{K}\zeta_{i,t,k}^{G2,\max}\overline{P}_{i,k}^{2}-\sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{k=1}^{K}\zeta_{j,t,k}^{D2,\max}\overline{D}_{j,k}^{2}=0$$

ii) 对于省内市场出清模型，将其原变量和对偶变量表示为：

$$\min\sum_{t=1}^{T}(\sum_{i=1}^{I}\sum_{k=1}^{K}\alpha_{i,k}^{1}P_{i,t,k}^{1}-\sum_{j=1}^{J}\sum_{k=1}^{K}\beta_{j,k}^{1}D_{j,t,k}^{1})$$

$$P_{i,t}=\sum_{k=1}^{K}P_{i,t,k}^{1}+\sum_{k=1}^{K}P_{i,t,k}^{2}:\chi_{i,t}^{G}$$

$$D_{j,t}=\sum_{k=1}^{K}D_{i,t,k}^{1}+\sum_{k=1}^{K}D_{i,t,k}^{2}:\chi_{j,t}^{D}$$

$$\sum_{i\in\Psi_n}P_{i,t}-\sum_{j\in\Phi_n}D_{j,t}=\sum_{l\in O_n}P_{l,t}-\sum_{l\in I_n}P_{l,t}+\sum_{l\in Co_n}P_{l,t}^{Ex}-\sum_{l\in Ci_n}P_{l,t}^{Ex}:\pi_{n,t}^{1}$$

$$0\leq P_{i,t,k}^{1}\leq\overline{P}_{i,k}^{1}:\zeta_{i,t,k}^{G1,\min},\zeta_{i,t,k}^{G1,\max}$$

$$0\leq D_{j,t,k}^{1}\leq\overline{D}_{j,k}^{1}:\zeta_{j,t,k}^{D1,\min},\zeta_{j,t,k}^{D1,\max}$$

$$-P_{i}^{rp}\leq P_{i,t}-P_{i,t+1}\leq P_{i}^{rp}:\eta_{i,t}^{\min},\eta_{i,t}^{\max}$$

$$P_{l,t}=\sum_{n=1}^{N}G_{l-n}(\sum_{i\in\Psi_n}P_{i,t}-\sum_{j\in\Phi_n}D_{j,t}):\vartheta_{l,t}$$

$$-\overline{P}_{l}\leq P_{l,t}\leq\overline{P}_{l}:\tau_{l,t}^{\min},\tau_{l,t}^{\max}$$

类似地，上述问题的形式同样为线性规划问题，其拉格朗日函数可以表示为：

$$L=\sum_{t=1}^{T}(\sum_{i=1}^{I}\sum_{k=1}^{K}\alpha_{i,k}^{1}P_{i,t,k}^{1}-\sum_{j=1}^{J}\sum_{k=1}^{K}\beta_{j,k}^{1}D_{j,t,k}^{1})$$

$$+\sum_{t=1}^{T}\sum_{i=1}^{I}\chi_{i,t}^{G}(P_{i,t}-\sum_{k=1}^{K}P_{i,t,k}^{1}-\sum_{k=1}^{K}P_{i,t,k}^{2})$$

$$+\sum_{t=1}^{T}\sum_{j=1}^{J}\chi_{j,t}^{D}(D_{j,t}-\sum_{k=1}^{K}D_{i,t,k}^{1}-\sum_{k=1}^{K}D_{i,t,k}^{2})$$

$$+\sum_{t=1}^{T}\sum_{n=1}^{N}\pi_{n,t}^{1}(\sum_{j\in\Phi_n}D_{j,t}-\sum_{i\in\Psi_n}P_{i,t}+\sum_{l\in O_n}P_{l,t}-\sum_{l\in I_n}P_{l,t}+\sum_{l\in Co_n}P_{l,t}^{Ex}-\sum_{l\in Ci_n}P_{l,t}^{Ex})$$

$$+\sum_{t=1}^{T}\sum_{l=1}^{L}\vartheta_{l,t}(P_{l,t}-\sum_{n=1}^{N}G_{l-n}(\sum_{i\in\Psi_n}P_{i,t}-\sum_{j\in\Phi_n}D_{j,t}))$$

$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{k=1}^{K}\zeta_{i,t,k}^{G1,\min}P_{i,t,k}^{1}$$

$$+\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{k=1}^{K}\zeta_{i,t,k}^{G1,\max}(P_{i,t,k}^{1}-\overline{P}_{i,k}^{1})$$

$$-\sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{k=1}^{K}\zeta_{j,t,k}^{D1,\min}D_{j,t,k}^{1}$$

$$+\sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{k=1}^{K}\zeta_{j,t,k}^{D1,\max}(D_{j,t,k}^{1}-\overline{D}_{j,k}^{1})$$

$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\eta_{i,t}^{\min}(P_{i,t}-P_{i,t+1}+P_{i}^{rp})$$

$$+\sum_{t=1}^{T}\sum_{i=1}^{I}\eta_{i,t}^{\max}(P_{i,t}-P_{i,t+1}-P_{i}^{rp})$$

$$-\sum_{t=1}^{T}\sum_{l=1}^{L}\tau_{l,t}^{\min}(P_{l,t}+\overline{P}_{l})$$

$$+\sum_{t=1}^{T}\sum_{l=1}^{L}\tau_{l,t}^{\max}(P_{l,t}-\overline{P}_{l})$$

其最优性条件可以表示为：

（原始可行）：

$$P_{i,t}=\sum_{k=1}^{K}P_{i,t,k}^{1}+\sum_{k=1}^{K}P_{i,t,k}^{2}$$

$$D_{j,t}=\sum_{k=1}^{K}D_{i,t,k}^{1}+\sum_{k=1}^{K}D_{i,t,k}^{2}$$

$$\sum_{i\in\Psi_n}P_{i,t}-\sum_{j\in\Phi_n}D_{j,t}=\sum_{l\in O_n}P_{l,t}-\sum_{l\in I_n}P_{l,t}+\sum_{l\in Co_n}P_{l,t}^{Ex}-\sum_{l\in Ci_n}P_{l,t}^{Ex}$$

$$0\le P_{i,t,k}^{1}\le\overline{P}_{i,k}^{1}$$

$$0\le D_{j,t,k}^{1}\le\overline{D}_{j,k}^{1}$$

$$-P_i^{rp} \le P_{i,t} - P_{i,t+1} \le P_i^{rp}$$

$$P_{l,t} = \sum_{n=1}^{N} G_{l-n} (\sum_{i \in \Psi_n} P_{i,t} - \sum_{j \in \Phi_n} D_{j,t})$$

$$-\overline{P}_l \le P_{l,t} \le \overline{P}_l$$

（对偶可行）：

$$\alpha_{i,k}^1 - \chi_{i,t}^G - \zeta_{i,t,k}^{G1,\min} + \zeta_{i,t,k}^{G1,\max} = 0$$

$$-\beta_{j,k}^1 - \chi_{j,t}^D - \zeta_{i,t,k}^{D1,\min} + \zeta_{i,t,k}^{D1,\max} = 0$$

$$\chi_{i,t}^G - \pi_{n,t}^1 - \sum_{l=1}^{L} \vartheta_{l,t} G_{l-n} - \eta_{i,t}^{\min} + \eta_{i,t}^{\max} + \eta_{i,t-1}^{\min} - \eta_{i,t-1}^{\max} = 0, i \in \Psi_n$$

$$\chi_{j,t}^D + \pi_{n,t}^1 + \sum_{l=1}^{L} \vartheta_{l,t} G_{l-n} = 0, j \in \Phi_n$$

$$\vartheta_{l,t} + \pi_{x,t}^1 - \pi_{y,t}^1 - \tau_{l,t}^{\min} + \tau_{l,t}^{\max} = 0, l \in O_x, l \in I_y$$

$$\zeta_{i,t,k}^{G1,\min}, \zeta_{i,t,k}^{G1,\max} \ge 0$$

$$\zeta_{j,t,k}^{D1,\min}, \zeta_{j,t,k}^{D1,\max} \ge 0$$

$$\eta_{i,t}^{\min}, \eta_{i,t}^{\max} \ge 0$$

$$\tau_{l,t}^{\min}, \tau_{l,t}^{\max} \ge 0$$

（强对偶条件）：

$$\sum_{t=1}^{T} (\sum_{i=1}^{I} \sum_{k=1}^{K} \alpha_{i,k}^1 P_{i,t,k}^1 - \sum_{j=1}^{J} \sum_{k=1}^{K} \beta_{j,k}^1 D_{j,t,k}^1) + \sum_{t=1}^{T} \sum_{n=1}^{N} \pi_{n,t}^1 (\sum_{l \in Co_n} P_{l,t}^{Ex} - \sum_{l \in Ci_n} P_{l,t}^{Ex})$$
$$-\sum_{t=1}^{T} \sum_{i=1}^{I} \sum_{k=1}^{K} \zeta_{i,t,k}^{G1,\max} \overline{P}_{i,k}^1 - \sum_{t=1}^{T} \sum_{j=1}^{J} \sum_{k=1}^{K} \zeta_{j,t,k}^{D1,\max} \overline{D}_{j,k}^1 - \sum_{t=1}^{T} \sum_{i=1}^{I} \eta_{i,t}^{\min} P_i^{rp} - \sum_{t=1}^{T} \sum_{i=1}^{I} \eta_{i,t}^{\max} P_i^{rp}$$
$$-\sum_{t=1}^{T} \sum_{l=1}^{L} \tau_{l,t}^{\min} \overline{P}_l - \sum_{t=1}^{T} \sum_{l=1}^{L} \tau_{l,t}^{\max} \overline{P}_l = 0$$

iii) 对于参与市场的策略型发电商 i，其在两个市场中的投标决策问题即可转化为 MPEC 问题，目标函数为最大化自身效益，约束条件为自身报价约束和两个市场最优性条件。该 MPEC 问题及其对偶变量可以表示为

$$\min \sum_{t=1}^{T} (\sum_{k=1}^{K} \lambda_{i,k} P_{i,t,k} - \pi_{i,t}^1 \sum_{k=1}^{K} P_{i,t,k}^1 - \pi_{i,t}^2 \sum_{k=1}^{K} P_{i,t,k}^2)$$

$$0 = \alpha_{i,0}^1 < \alpha_{i,1}^1 < \alpha_{i,2}^1 < ... < \alpha_{i,K}^1 : \omega_{i,k}^{\alpha,1}$$

$$0 = \alpha_{i,0}^2 < \alpha_{i,1}^2 < \alpha_{i,2}^2 < ... < \alpha_{i,K}^2 : \omega_{i,k}^{\alpha,2}$$

$$P_{i,t} = \sum_{k=1}^{K} P_{i,t,k} : \rho_{i,t}^G$$

$$0 \le P_{i,t,k} \le \overline{P}_{i,k} : \omega_{i,t,k}^{G\min,0}, \omega_{i,t,k}^{G\max,0}$$

$$P_{r,t} = \sum_{i \in X_r} \sum_{k=1}^{K} P_{i,t,k}^2 - \sum_{j \in Y_r} \sum_{k=1}^{K} D_{j,t,k}^2 : \rho_{r,t}^2$$

$$-\sum_{l\in Z_r}\overline{P}_l^{Ex} \le P_{r,t} \le \sum_{l\in Z_r}\overline{P}_l^{Ex} : \omega_{r,t}^{l\min,2}, \omega_{r,t}^{l\max,2}$$

$$0 \le P_{i,t,k}^2 \le \overline{P}_{i,k}^2 : \omega_{i,t,k}^{G\min,2}, \omega_{i,t,k}^{G\max,2}$$

$$0 \le D_{j,t,k}^2 \le \overline{D}_{j,k}^2 : \omega_{j,t,k}^{D\min,2}, \omega_{j,t,k}^{D\max,2}$$

$$\alpha_{i,k}^2 - \pi_{r,t}^2 + \zeta_{i,t,k}^{G2,\max} - \zeta_{i,t,k}^{G2,\min} = 0 : \gamma_{i,t,k}^{G,2}$$

$$-\beta_{j,k}^2 + \pi_{r,t}^2 + \zeta_{j,t,k}^{D2,\max} - \zeta_{j,t,k}^{D2,\min} = 0 : \gamma_{j,t,k}^{D,2}$$

$$\pi_{r,t}^2 - \tau_{r,t}^{Ex,\min} + \tau_{r,t}^{Ex,\max} = 0 : \gamma_{r,t}^{Ex}$$

$$\tau_{r,t}^{Ex,\min}, \tau_{r,t}^{Ex,\max} \ge 0 : \gamma_{r,t}^{Ex,\min}, \gamma_{r,t}^{Ex,\max}$$

$$\zeta_{i,t,k}^{G2,\max}, \zeta_{i,t,k}^{G2,\min} \ge 0 : \gamma_{i,t,k}^{G2,\min}, \gamma_{i,t,k}^{G2\quad ax}$$

$$\zeta_{j,t,k}^{D2,\max}, \zeta_{j,t,k}^{D2,\min} \ge 0 : \gamma_{j,t,k}^{D2,\min}, \gamma_{j,t,k}^{D2\quad ax}$$

$$\sum_{t=1}^{T}\Big(\sum_{i=1}^{I}\sum_{k=1}^{K}\alpha_{i,k}^2 P_{i,t,k}^2 - \sum_{j=1}^{J}\sum_{k=1}^{K}\beta_{j,k}^2 D_{j,t,k}^2\Big) - \sum_{t=1}^{T}\sum_{r}\tau_r^{Ex,\min}\sum_{l\in Z_r}\overline{P}_{l,t}^{Ex} - \sum_{t=1}^{T}\sum_{r}\tau_{r,t}^{Ex,\max}\sum_{l\in Z_r}\overline{P}_{l,t}^{Ex}$$

$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{k=1}^{K}\zeta_{i,t,k}^{G2,\max}\overline{P}_{i,k}^2 - \sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{k=1}^{K}\zeta_{j,t,k}^{D2,\max}\overline{D}_{j,k}^2 = 0 : \gamma^{DT,2}$$

$$P_{i,t} = \sum_{k=1}^{K}P_{i,t,k}^1 + \sum_{k=1}^{K}P_{i,t,k}^2 : \rho_{i,t}^{G'}$$

$$D_{j,t} = \sum_{k=1}^{K}D_{i,t,k}^1 + \sum_{k=1}^{K}D_{i,t,k}^2 : \rho_{j,t}^{D'}$$

$$\sum_{i\in\Psi_n}P_{i,t} - \sum_{j\in\Phi_n}D_{j,t} = \sum_{l\in O_n}P_{l,t} - \sum_{l\in I_n}P_{l,t} + \sum_{l\in Co_n}P_{l,t}^{Ex} - \sum_{l\in Ci_n}P_{l,t}^{Ex} : \rho_{n,t}^1$$

$$0 \le P_{i,t,k}^1 \le \overline{P}_{i,k}^1 : \omega_{i,t,k}^{G\min,1}, \omega_{i,t,k}^{G\max,1}$$

$$0 \le D_{j,t,k}^1 \le \overline{D}_{j,k}^1 : \omega_{j,t,k}^{D\min,1}, \omega_{j,t,k}^{D\max,1}$$

$$-P_i^{rp} \le P_{i,t} - P_{i,t+1} \le P_i^{rp} : \omega_{i,t}^{rp\min}, \omega_{i,t}^{rp\max}$$

$$P_{l,t} = \sum_{n=1}^{N}G_{l-n}\Big(\sum_{i\in\Psi_n}P_{i,t} - \sum_{j\in\Phi_n}D_{j,t}\Big) : \rho_{l,t}^L$$

$$-\overline{P}_l \le P_{l,t} \le \overline{P}_l : \omega_{l,t}^{L\min}, \omega_{l,t}^{L\max}$$

$$\alpha_{i,k}^1 - \chi_{i,t}^G - \zeta_{i,t,k}^{G1,\min} + \zeta_{i,t,k}^{G1,\max} = 0 : \gamma_{i,t,k}^{G,1}$$

$$-\beta_{j,k}^1 - \chi_{j,t}^D - \zeta_{i,t,k}^{D1,\min} + \zeta_{i,t,k}^{D1,\max} = 0 : \gamma_{j,t,k}^{D,1}$$

$$\chi_{i,t}^G - \pi_{n,t}^1 - \sum_{l=1}^{L}\vartheta_{l,t}G_{l-n} - \eta_{i,t}^{\min} + \eta_{i,t}^{\max} + \eta_{i,t-1}^{\min} - \eta_{i,t-1}^{\max} = 0, i\in\Psi_n : \gamma_{i,t}^G$$

$$\chi_{j,t}^D + \pi_{n,t}^1 + \sum_{l=1}^{L}\vartheta_{l,t}G_{l-n} = 0, j\in\Phi_n : \gamma_{j,t}^D$$

$$\vartheta_{l,t} + \pi_{x,t}^1 - \pi_{y,t}^1 - \tau_{l,t}^{\min} + \tau_{l,t}^{\max} = 0, l\in O_x, l\in I_y : \gamma_{l,t}^L$$

$$\zeta_{i,t,k}^{G1,\min}, \zeta_{i,t,k}^{G1,\max} \ge 0 : \gamma_{i,t,k}^{G1,\min}, \gamma_{i,t,k}^{G1,\max}$$

$$\zeta_{j,t,k}^{D1,\min}, \zeta_{j,t,k}^{D1,\max} \ge 0 : \gamma_{j,t,k}^{D1,\min}, \gamma_{j,t,k}^{D1,\max}$$

$$\eta_{i,t}^{\min}, \eta_{i,t}^{\max} \ge 0 : \gamma_{i,t}^{rp,\min}, \gamma_{i,t}^{rp,\max}$$

$$\tau_{l,t}^{\min},\tau_{l,t}^{\max}\geq 0:\gamma_{l,t}^{L,\min},\gamma_{l,t}^{L,\max}$$

$$\sum_{t=1}^{T}(\sum_{i=1}^{I}\sum_{k=1}^{K}\alpha_{i,k}^{1}P_{i,t,k}^{1}-\sum_{j=1}^{J}\sum_{k=1}^{K}\beta_{j,k}^{1}D_{j,t,k}^{1})+\sum_{t=1}^{T}\sum_{n=1}^{N}\pi_{n,t}^{1}(\sum_{l\in Co_n}P_{l,t}^{Ex}-\sum_{l\in Ci_n}P_{l,t}^{Ex})$$
$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{k=1}^{K}\zeta_{i,t,k}^{G1,\max}\overline{P}_{i,k}^{1}-\sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{k=1}^{K}\zeta_{j,t,k}^{D1,\max}\overline{D}_{j,k}^{1}-\sum_{t=1}^{T}\sum_{i=1}^{I}\eta_{i,t}^{\min}P_{i}^{rp}-\sum_{t=1}^{T}\sum_{i=1}^{I}\eta_{i,t}^{\max}P_{i}^{rp}$$
$$-\sum_{t=1}^{T}\sum_{l=1}^{L}\tau_{l,t}^{\min}\overline{P}_{l}-\sum_{t=1}^{T}\sum_{l=1}^{L}\tau_{l,t}^{\max}\overline{P}_{l}=0:\gamma^{DT,1}$$

iv) 对于每一个市场参与者（市场主体），可以建立其优化决策模型的拉格朗日函数，并列写其 KKT 条件：

（原始可行）：

$$0=\alpha_{i,0}^{1}<\alpha_{i,1}^{1}<\alpha_{i,2}^{1}<...<\alpha_{i,K}^{1}$$
$$0=\alpha_{i,0}^{2}<\alpha_{i,1}^{2}<\alpha_{i,2}^{2}<...<\alpha_{i,K}^{2}$$
$$\beta_{j,1}^{1}>\beta_{j,2}^{1}>...>\beta_{j,K}^{1}>\beta_{j,0}^{1}=0$$
$$\beta_{j,1}^{2}>\beta_{j,2}^{2}>...>\beta_{j,K}^{2}>\beta_{j,0}^{2}=0$$
$$P_{r,t}=\sum_{i\in X_r}\sum_{k=1}^{K}P_{i,t,k}^{2}-\sum_{j\in Y_r}\sum_{k=1}^{K}D_{j,t,k}^{2}$$
$$-\sum_{l\in Z_r}\overline{P}_{l}^{Ex}\leq P_{r,t}\leq\sum_{l\in Z_r}\overline{P}_{l}^{Ex}$$
$$0\leq P_{i,t,k}^{2}\leq\overline{P}_{i,k}^{2}$$
$$0\leq D_{j,t,k}^{2}\leq\overline{D}_{j,k}^{2}$$
$$\alpha_{i,k}^{2}-\pi_{r,t}^{2}+\zeta_{i,t,k}^{G2,\max}-\zeta_{i,t,k}^{G2,\min}=0$$
$$-\beta_{j,k}^{2}+\pi_{r,t}^{2}+\zeta_{j,t,k}^{D2,\max}-\zeta_{j,t,k}^{D2,\min}=0$$
$$\pi_{r,t}^{2}-\tau_{r,t}^{Ex,\min}+\tau_{r,t}^{Ex,\max}=0$$
$$\tau_{r,t}^{Ex,\min},\tau_{r,t}^{Ex,\max}\geq 0$$
$$\zeta_{i,t,k}^{G2,\max},\zeta_{i,t,k}^{G2,\min}\geq 0$$
$$\zeta_{j,t,k}^{D2,\max},\zeta_{j,t,k}^{D2,\min}\geq 0$$

$$\sum_{t=1}^{T}(\sum_{i=1}^{I}\sum_{k=1}^{K}\alpha_{i,k}^{2}P_{i,t,k}^{2}-\sum_{j=1}^{J}\sum_{k=1}^{K}\beta_{j,k}^{2}D_{j,t,k}^{2})-\sum_{t=1}^{T}\sum_{r}\tau_{r}^{Ex,\min}\sum_{l\in Z_r}\overline{P}_{l,t}^{Ex}-\sum_{t=1}^{T}\sum_{r}\tau_{r,t}^{Ex,\max}\sum_{l\in Z_r}\overline{P}_{l,t}^{Ex}$$
$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{k=1}^{K}\zeta_{i,t,k}^{G,\max}\overline{P}_{i,k}^{2}-\sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{k=1}^{K}\zeta_{j,t,k}^{D,\max}\overline{D}_{j,k}^{2}=0$$

$$P_{i,t}=\sum_{k=1}^{K}P_{i,t,k}^{1}+\sum_{k=1}^{K}P_{i,t,k}^{2}$$
$$D_{j,t}=\sum_{k=1}^{K}D_{i,t,k}^{1}+\sum_{k=1}^{K}D_{i,t,k}^{2}$$
$$\sum_{i\in\Psi_n}P_{i,t}-\sum_{j\in\Phi_n}D_{j,t}=\sum_{l\in O_n}P_{l,t}-\sum_{l\in I_n}P_{l,t}+\sum_{l\in Co_n}P_{l,t}^{Ex}-\sum_{l\in Ci_n}P_{l,t}^{Ex}$$

$$0 \le P_{i,t,k}^{1} \le \overline{P}_{i,k}^{1}$$

$$0 \le D_{j,t,k}^{1} \le \overline{D}_{j,k}^{1}$$

$$-P_{i}^{rp} \le P_{i,t} - P_{i,t+1} \le P_{i}^{rp}$$

$$P_{l,t} = \sum_{n=1}^{N} G_{l-n} (\sum_{i \in \Psi_n} P_{i,t} - \sum_{j \in \Phi_n} D_{j,t})$$

$$-\overline{P}_{l} \le P_{l,t} \le \overline{P}_{l}$$

$$\alpha_{i,k}^{1} - \chi_{i,t}^{G} - \zeta_{i,t,k}^{G1,\min} + \zeta_{i,t,k}^{G1,\max} = 0$$

$$-\beta_{j,k}^{1} - \chi_{j,t}^{D} - \zeta_{i,t,k}^{D1,\min} + \zeta_{i,t,k}^{D1,\max} = 0$$

$$\chi_{i,t}^{G} - \pi_{n,t}^{1} - \sum_{l=1}^{L} \vartheta_{l,t} G_{l-n} - \eta_{i,t}^{\min} + \eta_{i,t}^{\max} + \eta_{i,t-1}^{\min} - \eta_{i,t-1}^{\max} = 0, i \in \Psi_n$$

$$\chi_{j,t}^{D} + \pi_{n,t}^{1} + \sum_{l=1}^{L} \vartheta_{l,t} G_{l-n} = 0, j \in \Phi_n$$

$$\vartheta_{l,t} + \pi_{x,t}^{1} - \pi_{y,t}^{1} - \tau_{l,t}^{\min} + \tau_{l,t}^{\max} = 0, l \in O_x, l \in I_y$$

$$\zeta_{i,t,k}^{G1,\min}, \zeta_{i,t,k}^{G1,\max} \ge 0$$

$$\zeta_{j,t,k}^{D1,\min}, \zeta_{j,t,k}^{D1,\max} \ge 0$$

$$\eta_{i,t}^{\min}, \eta_{i,t}^{\max} \ge 0$$

$$\tau_{l,t}^{\min}, \tau_{l,t}^{\max} \ge 0$$

$$\sum_{t=1}^{T} (\sum_{i=1}^{I} \sum_{k=1}^{K} \alpha_{i,k}^{1} P_{i,t,k}^{1} - \sum_{j=1}^{J} \sum_{k=1}^{K} \beta_{j,k}^{1} D_{j,t,k}^{1}) + \sum_{t=1}^{T} \sum_{n=1}^{N} \pi_{n,t}^{1} (\sum_{l \in Co_n} P_{l,t}^{Ex} - \sum_{l \in Ci_n} P_{l,t}^{Ex})$$
$$- \sum_{t=1}^{T} \sum_{i=1}^{I} \sum_{k=1}^{K} \zeta_{i,t,k}^{G1,\max} \overline{P}_{i,k}^{1} - \sum_{t=1}^{T} \sum_{j=1}^{J} \sum_{k=1}^{K} \zeta_{j,t,k}^{D1,\max} \overline{D}_{j,k}^{1} - \sum_{t=1}^{T} \sum_{i=1}^{I} \eta_{i,t}^{\min} P_{i}^{rp} - \sum_{t=1}^{T} \sum_{i=1}^{I} \eta_{i,t}^{\max} P_{i}^{rp}$$
$$- \sum_{t=1}^{T} \sum_{l=1}^{L} \tau_{l,t}^{\min} \overline{P}_{l} - \sum_{t=1}^{T} \sum_{l=1}^{L} \tau_{l,t}^{\max} \overline{P}_{l} = 0$$

（对偶可行）：

$$\frac{\partial L}{\partial P_{i,t,k}} = \lambda_{i,k} - \rho_{i,t}^{G} - \omega_{i,t,k}^{G\min,0} + \omega_{i,t,k}^{G\max,0} = 0$$

$$\frac{\partial L}{\partial P_{i,t,k}^{1}} = -\pi_{i,t}^{1} - \rho_{i,t}^{G'} - \omega_{i,t,k}^{G\min,1} + \omega_{i,t,k}^{G\max,1} + \alpha_{i,k}^{1} \gamma^{DT,1} = 0$$

$$\frac{\partial L}{\partial P_{i,t,k}^{2}} = -\pi_{i,t}^{2} - \rho_{r,t}^{2} - \rho_{i,t}^{G'} - \omega_{i,t,k}^{G\min,2} + \omega_{i,t,k}^{G\max,2} + \alpha_{i,k}^{2} \gamma^{DT,2} = 0$$

$$\frac{\partial L}{\partial \alpha_{i,k}^{1}} = -\omega_{i,k}^{\alpha,1} + \omega_{i,k-1}^{\alpha,1} + \sum_{t=1}^{T} \gamma_{i,t,k}^{G,1} + \gamma^{DT,1} \sum_{t=1}^{T} P_{i,t,k}^{1} = 0$$

$$\frac{\partial L}{\partial \alpha_{i,k}^{2}} = -\omega_{i,k}^{\alpha,2} + \omega_{i,k-1}^{\alpha,2} + \sum_{t=1}^{T} \gamma_{i,t,k}^{G,2} + \gamma^{DT,2} \sum_{t=1}^{T} P_{i,t,k}^{2} = 0$$

$$\frac{\partial L}{\partial D_{j,t,k}} = -\mu_{j,k} - \rho_{j,t}^{D} - \omega_{j,t,k}^{D\min,0} + \omega_{j,t,k}^{D\max,0} = 0$$

$$\frac{\partial L}{\partial D_{j,t,k}^{1}} = \pi_{j,t}^{1} - \rho_{i,t}^{D'} - \omega_{i,t,k}^{D\min,1} + \omega_{i,t,k}^{G\max,1} - \beta_{i,k}^{1}\gamma^{DT,1} = 0$$

$$\frac{\partial L}{\partial D_{j,t,k}^{2}} = \pi_{i,t}^{2} + \rho_{r,t}^{2} - \rho_{i,t}^{D'} - \omega_{j,t,k}^{D\min,2} + \omega_{j,t,k}^{D\max,2} - \beta_{j,k}^{2}\gamma^{DT,2} = 0$$

$$\frac{\partial L}{\partial \beta_{j,k}^{1}} = \omega_{j,k}^{\beta,1} - \omega_{j,k-1}^{\beta,1} - \sum_{t=1}^{T}\gamma_{j,t,k}^{D,1} - \gamma^{DT,1}\sum_{t=1}^{T}D_{j,t,k}^{1} = 0$$

$$\frac{\partial L}{\partial \beta_{j,k}^{2}} = \omega_{j,k}^{\beta,2} + \omega_{j,k-1}^{\beta,2} - \sum_{t=1}^{T}\gamma_{j,t,k}^{D,2} - \gamma^{DT,2}\sum_{t=1}^{T}D_{j,t,k}^{2} = 0$$

$$\frac{\partial L}{\partial \pi_{n,t}^{1}} = -\sum_{k=1}^{K}P_{i,t,k}^{1} - \sum_{k=1}^{K}\gamma_{i,t,k}^{G} + \sum_{l=O_n}\gamma_{l,t}^{L} - \sum_{l=I_n}\gamma_{l,t}^{L} + \gamma^{DT,1}\left(\sum_{l\in Co_n}P_{l,t}^{Ex} - \sum_{l\in Ci_n}P_{l,t}^{Ex}\right) = 0, i\in\Psi_n$$

$$\frac{\partial L}{\partial \pi_{n,t}^{1}} = \sum_{k=1}^{K}D_{j,t,k}^{1} - \sum_{k=1}^{K}\gamma_{j,t,k}^{D} + \sum_{l=O_n}\gamma_{l,t}^{L} - \sum_{l=I_n}\gamma_{l,t}^{L} + \gamma^{DT,1}\left(\sum_{l\in Co_n}P_{l,t}^{Ex} - \sum_{l\in Ci_n}P_{l,t}^{Ex}\right) = 0, j\in\Phi_n$$

$$\frac{\partial L}{\partial \pi_{r,t}^{2}} = -\sum_{k=1}^{K}P_{i,t,k}^{2} - \sum_{k=1}^{K}\gamma_{i,t,k}^{G,2} + \gamma_{r,t}^{Ex} = 0, i\in\Psi_r$$

$$\frac{\partial L}{\partial \pi_{r,t}^{2}} = \sum_{k=1}^{K}D_{j,t,k}^{2} + \sum_{k=1}^{K}\gamma_{j,t,k}^{D,2} + \gamma_{r,t}^{Ex} = 0, i\in\Phi_r$$

$$\frac{\partial L}{\partial P_{i,t}} = \rho_{i,t}^{G} + \rho_{i,t}^{G'} + \rho_{n,t}^{1} + \omega_{i,t}^{rp\min} - \omega_{i,t}^{rp\max} - \sum_{l\in O_n or l\in I_n}\rho_{l,t}^{L}G_{l-n} = 0$$

$$\frac{\partial L}{\partial D_{j,t}} = \rho_{j,t}^{D} + \rho_{j,t}^{D'} - \rho_{n,t}^{1} + \sum_{l\in O_n or l\in I_n}\rho_{l,t}^{L}G_{l-n} = 0$$

$$\frac{\partial L}{\partial P_{r,t}} = \rho_{r,t}^{2} - \omega_{r,t}^{l\min,2} + \omega_{r,t}^{l\max,2} = 0$$

$$\frac{\partial L}{\partial \zeta_{i,t,k}^{G2,\max}} = \gamma_{i,t,k}^{G,2} - \gamma_{i,t,k}^{G2,\max} - \gamma^{DT,2}\overline{P}_{i,k}^{2} = 0$$

$$\frac{\partial L}{\partial \zeta_{i,t,k}^{G2,\min}} = -\gamma_{i,t,k}^{G,2} - \gamma_{i,t,k}^{G2,\min} = 0$$

$$\frac{\partial L}{\partial \zeta_{j,t,k}^{D2,\max}} = \gamma_{j,t,k}^{D,2} - \gamma_{j,t,k}^{D2,\max} - \gamma^{DT,2}P\overline{D}_{j,k}^{2} = 0$$

$$\frac{\partial L}{\partial \zeta_{j,t,k}^{D2,\min}} = -\gamma_{j,t,k}^{D,2} - \gamma_{j,t,k}^{D2,\min} = 0$$

$$\frac{\partial L}{\partial \tau_{r,t}^{Ex,\max}} = \gamma_{r,t}^{Ex} - \gamma_{r,t}^{Ex,\max} - \gamma^{DT,2}\sum_{l\in Z_r}\overline{P}_{l,t}^{Ex} = 0$$

$$\frac{\partial L}{\partial \tau_{r,t}^{Ex,\min}} = -\gamma_{r,t}^{Ex} - \gamma_{r,t}^{Ex,\min} - \gamma^{DT,2}\sum_{l\in Z_r}\overline{P}_{l,t}^{Ex} = 0$$

$$\frac{\partial L}{\partial P_{l,t}} = \rho_{,}^{L} + \rho_{,}^{1} - \rho_{y,t}^{1} - \omega_{l,t}^{L\min} + \omega_{l,t}^{L\max} = 0, l\in O_x, l\in I_y$$

$$\frac{\partial L}{\partial \chi_{i,t}^{G}} = -\sum_{k=1}^{K} \gamma_{i,t,k}^{G,1} + \gamma_{i,t}^{G} = 0$$

$$\frac{\partial L}{\partial \chi_{j,t}^{D}} = -\sum_{k=1}^{K} \gamma_{j,t,k}^{D,1} + \gamma_{j,t}^{D} = 0$$

$$\frac{\partial L}{\partial \zeta_{i,t,k}^{G1,\min}} = -\gamma_{i,t,k}^{G,1} - \gamma_{i,t,k}^{G1,\min} = 0$$

$$\frac{\partial L}{\partial \zeta_{i,t,k}^{G1,\max}} = \gamma_{i,t,k}^{G,1} - \gamma_{i,t,k}^{G1,\max} - \gamma^{DT,1} \overline{P}_{i,k}^{1} = 0$$

$$\frac{\partial L}{\partial \zeta_{j,t,k}^{D1,\min}} = -\gamma_{j,t,k}^{D,1} - \gamma_{j,t,k}^{D1,\min} = 0$$

$$\frac{\partial L}{\partial \zeta_{j,t,k}^{D1,\max}} = \gamma_{j,t,k}^{D,1} - \gamma_{j,t,k}^{D1,\max} - \gamma^{DT,1} \overline{D}_{j,k}^{1} = 0$$

$$\frac{\partial L}{\partial \eta_{i,t}^{\min}} = -\gamma_{i,t}^{G} + \gamma_{i,t-1}^{G} - \gamma_{i,t}^{rp,\min} - \gamma^{DT,1} P_{i}^{rp} = 0$$

$$\frac{\partial L}{\partial \eta_{i,t}^{\max}} = \gamma_{i,t}^{G} - \gamma_{i,t-1}^{G} - \gamma_{i,t}^{rp,\max} - \gamma^{DT,1} P_{i}^{rp} = 0$$

$$\frac{\partial L}{\partial \vartheta_{l,t}} = \sum_{n=1}^{N} G_{l-n} \left(\sum_{j \in \Phi_n} \gamma_{j,t}^{D} - \sum_{i \in \Psi_n} \gamma_{i,t}^{G} \right) + \gamma_{l,t}^{L} = 0$$

$$\frac{\partial L}{\partial \tau_{l,t}^{\min}} = -\gamma_{l,t}^{L} - \gamma_{i,t}^{rp,\min} - \gamma^{DT,1} \overline{P}_{l} = 0$$

$$\frac{\partial L}{\partial \tau_{l,t}^{\max}} = \gamma_{l,t}^{L} - \gamma_{i,t}^{rp,\max} - \gamma^{DT,1} \overline{P}_{l} = 0$$

（互补松弛条件）：

$$\alpha_{i,k-1}^{1} \le \alpha_{i,k-1}^{1} \perp \omega_{i,k}^{\alpha,1} \ge 0$$

$$\alpha_{i,k-1}^{2} \le \alpha_{i,k-1}^{2} \perp \omega_{i,k}^{\alpha,2} \ge 0$$

$$\beta_{i,k-1}^{1} \ge \beta_{i,k-1}^{1} \perp \omega_{i,k}^{\beta,1} \ge 0$$

$$\beta_{i,k-1}^{2} \ge \beta_{i,k-1}^{2} \perp \omega_{i,k}^{\beta,2} \ge 0$$

$$0 \le P_{i,t,k} \perp \omega_{i,t,k}^{G\min,0} \ge 0$$

$$P_{i,t,k} \le \overline{P}_{i,k} \perp \omega_{i,t,k}^{G\max,0} \ge 0$$

$$-\sum_{l \in Z_r} \overline{P}_{l}^{Ex} \le P_{r,t} \perp \omega_{r,t}^{l\min,2} \ge 0$$

$$P_{r,t} \le \sum_{l \in Z_r} \overline{P}_{l}^{Ex} \perp \omega_{r,t}^{l\max,2} \ge 0$$

$$0 \le P_{i,t,k}^{2} \perp \omega_{i,t,k}^{G\min,2} \ge 0$$

$$P_{i,t,k}^{2} \le \overline{P}_{i,k}^{2} \perp \omega_{i,t,k}^{G\max,2} \ge 0$$

$$0 \le D_{j,t,k}^{2} \perp \omega_{j,t,k}^{D\min,2} \ge 0$$

$$D_{j,t,k}^{2} \le \overline{D}_{j,k}^{2} \perp \omega_{j,t,k}^{D\max,2} \ge 0$$

$$\tau_{r,t}^{Ex,\min} \ge 0 \perp \gamma_{r,t}^{Ex,\min} \ge 0$$
$$\tau_{r,t}^{Ex,\max} \ge 0 \perp \gamma_{r,t}^{Ex,\max} \ge 0$$
$$\zeta_{i,t,k}^{G2,\min} \ge 0 \perp \gamma_{i,t,k}^{G2,\min} \ge 0$$
$$\zeta_{i,t,k}^{G2,\max} \ge 0 \perp \gamma_{i,t,k}^{G2,\max} \ge 0$$
$$\zeta_{j,t,k}^{D2,\min} \ge 0 \perp \gamma_{j,t,k}^{D2,\min} \ge 0$$
$$\zeta_{j,t,k}^{D2,\max} \ge 0 \perp \gamma_{j,t,k}^{D2,\max} \ge 0$$
$$0 \le P_{i,t,k}^{1} \perp \omega_{i,t,k}^{G\min,1} \ge 0$$
$$P_{i,t,k}^{1} \le \overline{P}_{i,k}^{1} \perp \omega_{i,t,k}^{G\max,1} \ge 0$$
$$0 \le D_{j,t,k}^{1} \perp \omega_{j,t,k}^{D\min,1} \ge 0$$
$$D_{j,t,k}^{1} \le \overline{D}_{j,k}^{1} \perp \omega_{j,t,k}^{D\max,1} \ge 0$$
$$-P_{i}^{rp} \le P_{i,t} - P_{i,t+1} \perp \omega_{i,t}^{rp\min} \ge 0$$
$$P_{i,t} - P_{i,t+1} \le P_{i}^{rp} \perp \omega_{i,t}^{rp\max} \ge 0$$
$$-\overline{P}_{l} \le P_{l,t} \perp \omega_{l,t}^{L\min} \ge 0$$
$$P_{l,t} \le \overline{P}_{l} \perp \omega_{l,t}^{L\max} \ge 0$$
$$\zeta_{i,t,k}^{G1,\min} \ge 0 \perp \gamma_{i,t,k}^{G1,\min} \ge 0$$
$$\zeta_{i,t,k}^{G1,\max} \ge 0 \perp \gamma_{i,t,k}^{G1,\max} \ge 0$$
$$\zeta_{j,t,k}^{D1,\min} \ge 0 \perp \gamma_{j,t,k}^{D1,\min} \ge 0$$
$$\zeta_{j,t,k}^{D1,\max} \ge 0 \perp \gamma_{j,t,k}^{D1,\max} \ge 0$$
$$\eta_{i,t}^{\min} \ge 0 \perp \gamma_{i,t}^{rp,\min} \ge 0$$
$$\eta_{i,t}^{\max} \ge 0 \perp \gamma_{i,t}^{rp,\max} \ge 0$$
$$\tau_{l,t}^{\min} \ge 0 \perp \gamma_{l,t}^{L,\min} \ge 0$$
$$\tau_{l,t}^{\max} \ge 0 \perp \gamma_{l,t}^{L,\max} \ge 0$$

通过上述模型转化，建立了对应的 EPEC 模型，理论上求解该模型即可获得在策略型竞价模式下，市场参与者（市场主体）的最优行为。然而，在 EPEC 模型的转化过程中，引入了大量的变量相乘和互补松弛约束，导致 EPEC 模型的实际求解存在较大困难。