2023年清华大学-IET电气工程学术论坛

Robust Pricing Strategy with EV Retailers Considering the Uncertainty of EVs and Electricity Market

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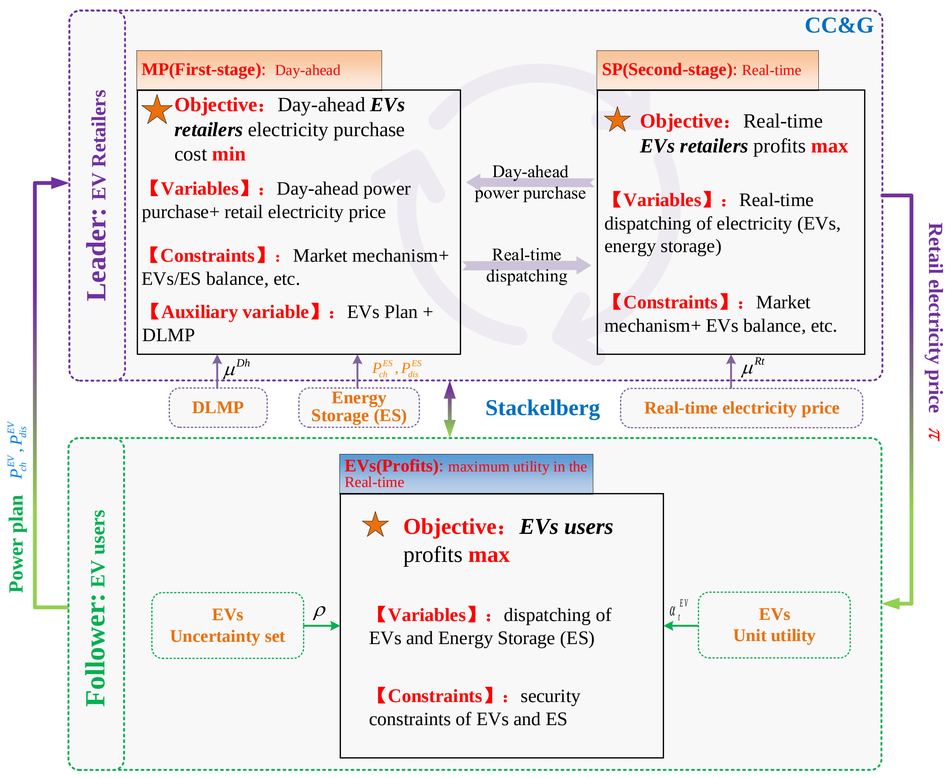
Background and Motivation

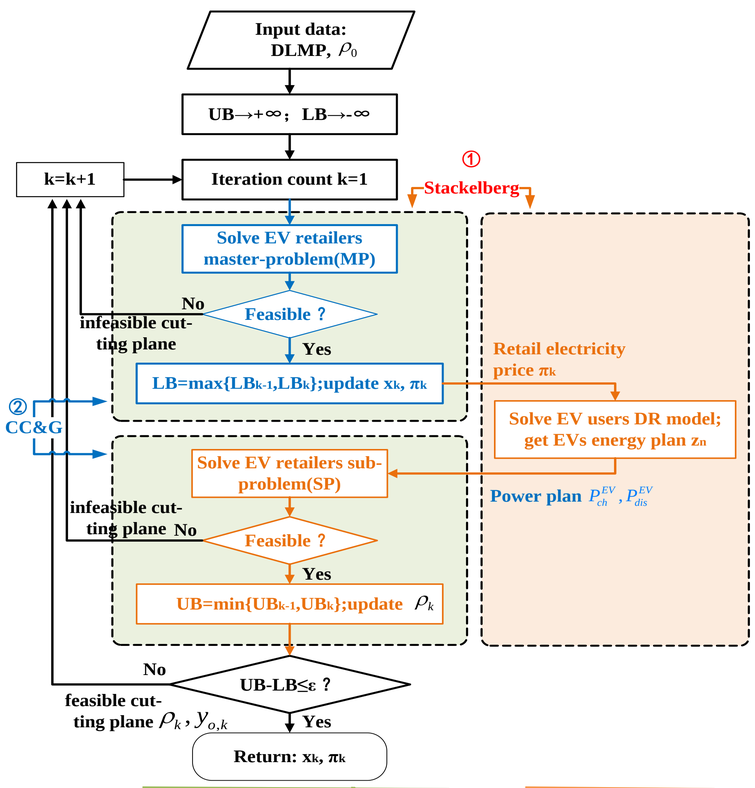
- As a bridge between the distribution network and electric vehicles (EVs), the operational efficiency of EV retailers directly determines the value of EV promotion and application.
- EV retailers face dual uncertainties of EV power demand and electricity market risks and must develop optimal management strategies that meet the needs of both themselves and EV users.

EV Retailers' Robust Pricing Strategy in Electricity Market Process



Two-Stage Robust Optimization Strategy Based on Stackelberg and CC&G

- The above model is a two-stage robust optimal problem based on Stackelberg and can be directly solved through CC&G, KKT, and strong duality.

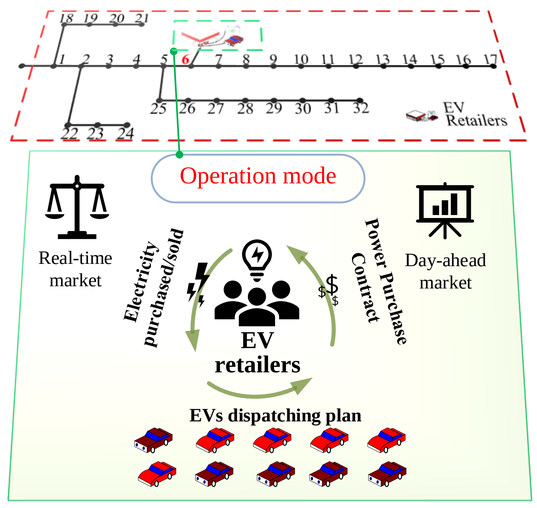


EV Retailers profits

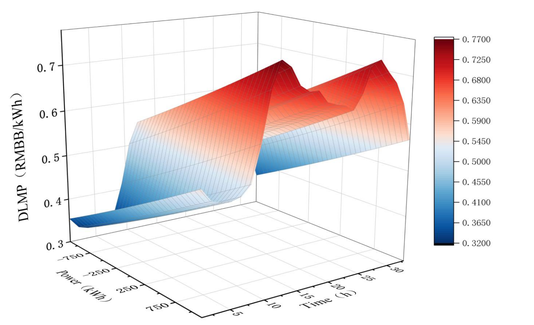
EVs profits

$$\begin{cases} \max\limits_{\{x,\pi\}} \boldsymbol{a}^T\boldsymbol{x} + \min\limits_{\{\rho\in\mathcal{R},\boldsymbol{y}_o\in Y,\forall o\in O\}} \max \left(\sum_{o\in O} \boldsymbol{v}_o \boldsymbol{b}_o^T \boldsymbol{y}_o + \boldsymbol{N}_{EV}\boldsymbol{z}\rho[\boldsymbol{\pi}_{ch}^T - \boldsymbol{\pi}_{dis}^T]\right) \\ \text{s.t. } \boldsymbol{A}\boldsymbol{x} + \boldsymbol{B}\boldsymbol{y}_o + \boldsymbol{C}\boldsymbol{z}\rho = \boldsymbol{0},\ \forall o \in \mathcal{O} \\ \max\limits_{z_n=\{p^{EV}_{ch,n,t}, p^{EV}_{dis,n,t}, \forall t\in T\}} \mathbb{E}(DR_n^{EV}) = \sum_{t\in T_n^{EV}} [\alpha_{n,t}^{EV}(\eta_{ch}^{EV} p_{ch,n,t}^{EV} - \frac{p_{dis,n,t}^{EV}}{\eta_{dis}^{EV}}) \\ \qquad -\pi_t(p_{ch,n,t}^{EV} - p_{dis,n,t}^{EV})],\ \forall n \in \mathcal{N}^{EV} \end{cases}$$

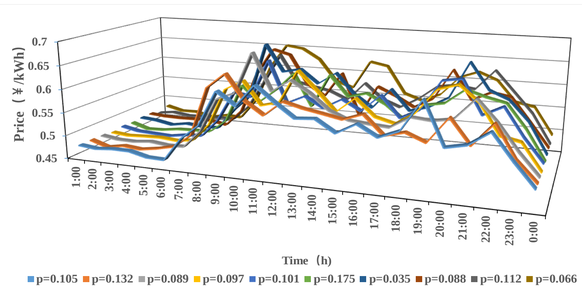
Simulation results: IEEE 33 System with EV Retailers



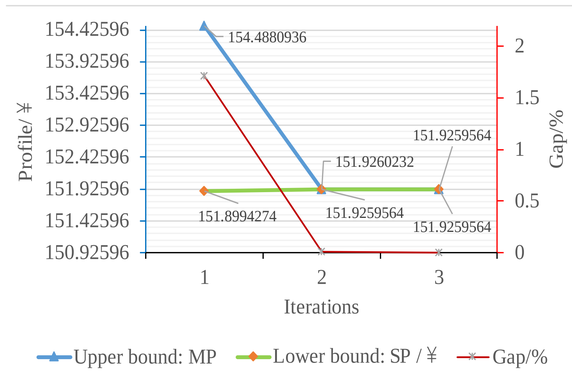
Operation strategy of EV retailers (node 6)



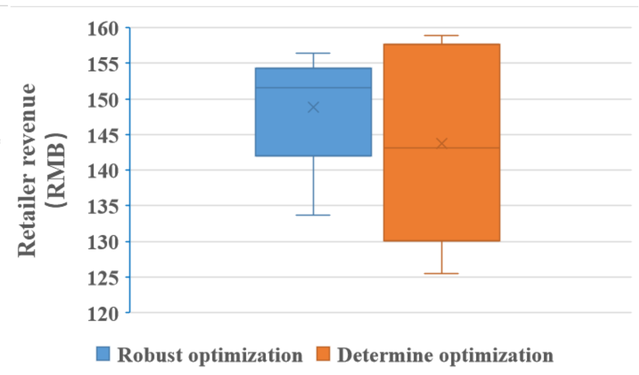
The relationship between EV retailer scheduling power and DLMP



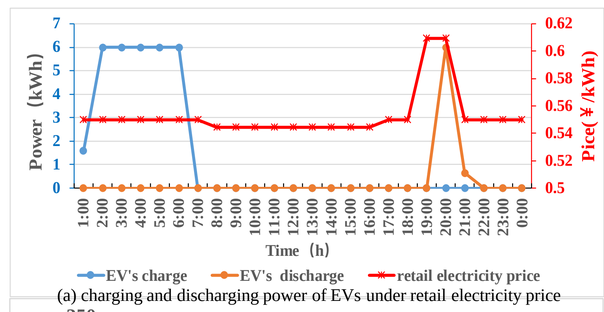
Real-time DLMP



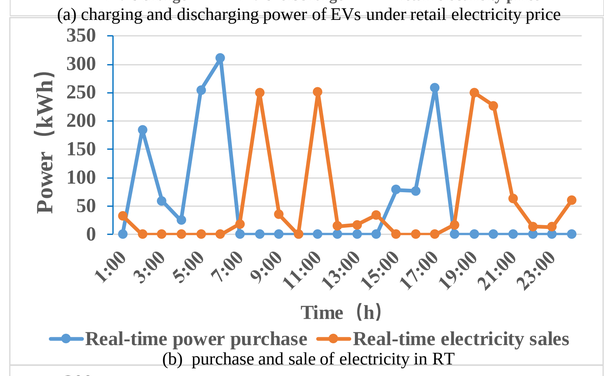
Convergence illustration



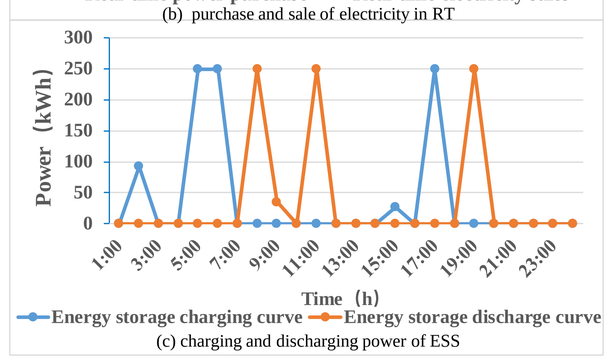
Boxplot of profit in different models



(a) charging and discharging power of EVs under retail electricity price

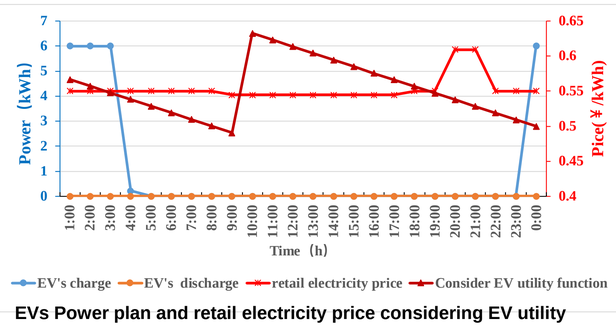


(b) purchase and sale of electricity in RT



(c) charging and discharging power of ESS

Curve of EV retailer power in Real-time(p=0.105)



EVs Power plan and retail electricity price considering EV utility

- Based on the retail electricity prices set by EV retailers, EVs can achieve charging and discharging plans during off peak hours.
- Real-time electricity purchase and sale by EV retailers followed a profit-making pattern of buying electricity during low-price periods and selling during high-price periods.
- Energy storage serves as a flexible unit for EV retailers, and its charging and discharging status is consistent with that of EV retailers.
- In order to obtain greater profits from EV users, EV retailers set retail electricity prices to track changes in EV user utility.