Analyzing the Impact of Strategic Bidding on the Reserve Capacity via a Bi-Level Model

Yun Xu[1], Yunxiao Bai[1], Yunyong Zhang[1], Jiqun Guo[1], Kaijun Xie[1], Peng Wang[2], Xuelin Wang[2], Rusheng Zhao[2]
1.Guangdong Power Exchange Center Co., Ltd
2.Sichuan Energy Internet Research Institute, Tsinghua University

Abstract & Background

Abstract:

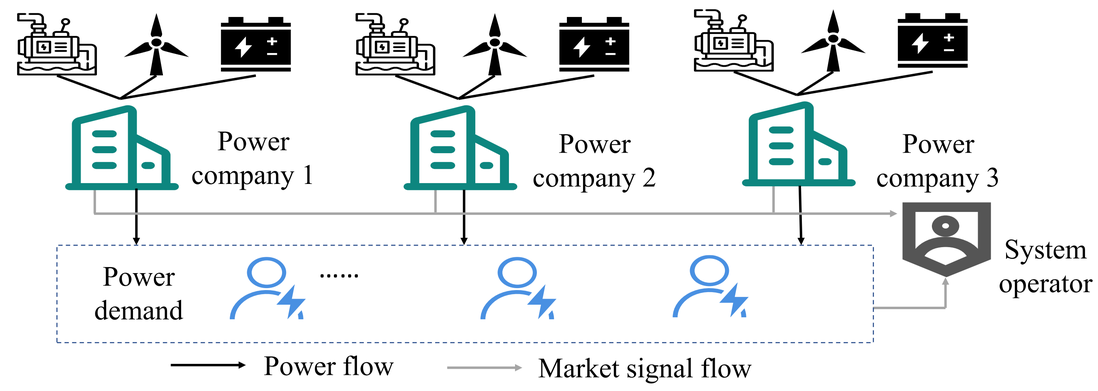
Sufficient system reserve is essential in the new power system; nevertheless, the market power exerted by specific trading participants can undermine it. This study proposes a bi-level optimization model, with the upper level aiming to maximize the strategic bidding profits of market participants, and the lower level modeling market clearing to assess the impact of such strategic bidding behavior. The results demonstrate that within an imperfectly competitive market, increasing system reserve leads to higher electricity costs for consumers.

Background:

- The presence of multiple sources of uncertainty complicates power system balancing, thereby elevating the requirement for system reserves.
- Within the market environment, the behaviors of trading entities can indirectly influence the reserve capacity of the power system.

Methods

This study develops a bi-level model coupled with a market power quantification approach: at the upper level (UL), the strategic power producer aims to maximize its profits via strategic bidding, whereas at the lower level (LL), the system operator (SO) endeavors to minimize the overall system operating costs.



UL Model

$$\max_{k_t} \sum_t \left[\lambda_t P_{\mathrm{SG},t}^{\mathrm{str}} - \mathrm{O}_{\mathrm{SG}}^{\mathrm{str}} P_{\mathrm{SG},t}^{\mathrm{str}} - \mathrm{O}_{\mathrm{BS}}^{\mathrm{str}} {P_{\mathrm{BS},t}^{\mathrm{str}}}^2 \right]$$

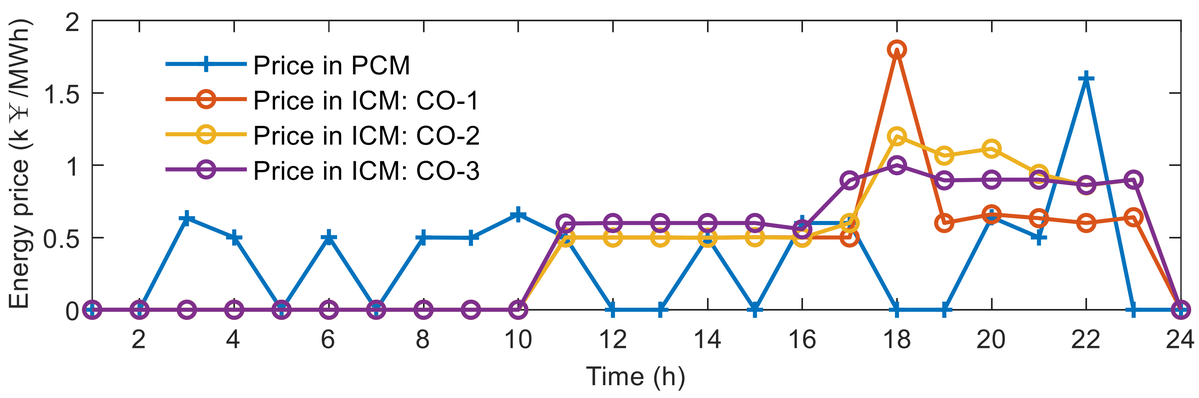
LL Model

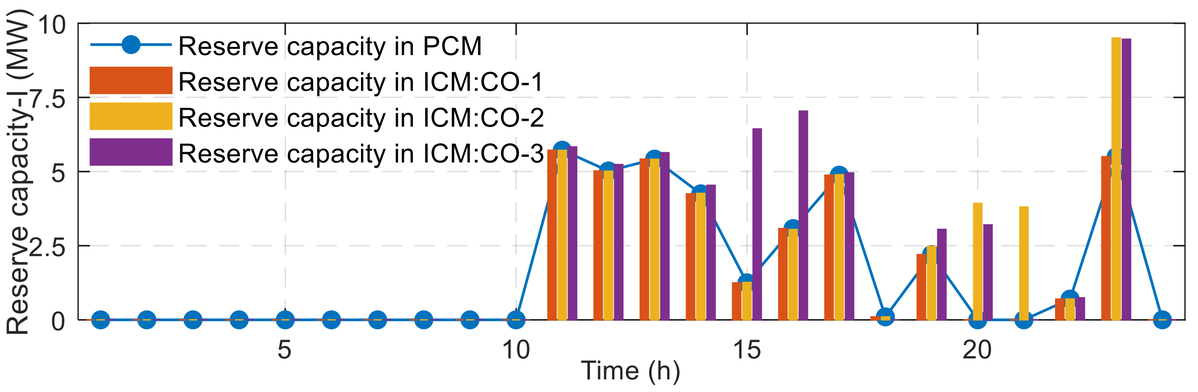
$$\min \sum_t \left[\begin{array}{l} \sum\limits_{\mathrm{SG}^{\mathrm{str}}} k_t \mathrm{O}_{\mathrm{SG}}^{\mathrm{str}} P_{\mathrm{SG},t}^{\mathrm{str}} + \sum\limits_{\mathrm{BS}^{\mathrm{str}}} \mathrm{O}_{\mathrm{BS}}^{\mathrm{str}} {P_{\mathrm{BS},t}^{\mathrm{str}}}^2 \\ + \sum\limits_{\mathrm{SG}^{\mathrm{n\text{-}str}}} \mathrm{O}_{\mathrm{SG}}^{\mathrm{n\text{-}str}} P_{\mathrm{SG},t}^{\mathrm{n\text{-}str}} + \sum\limits_{\mathrm{BS}^{\mathrm{str}}} \mathrm{O}_{\mathrm{BS}}^{\mathrm{n\text{-}str}} {P_{\mathrm{BS},t}^{\mathrm{n\text{-}str}}}^2 \end{array} \right]$$

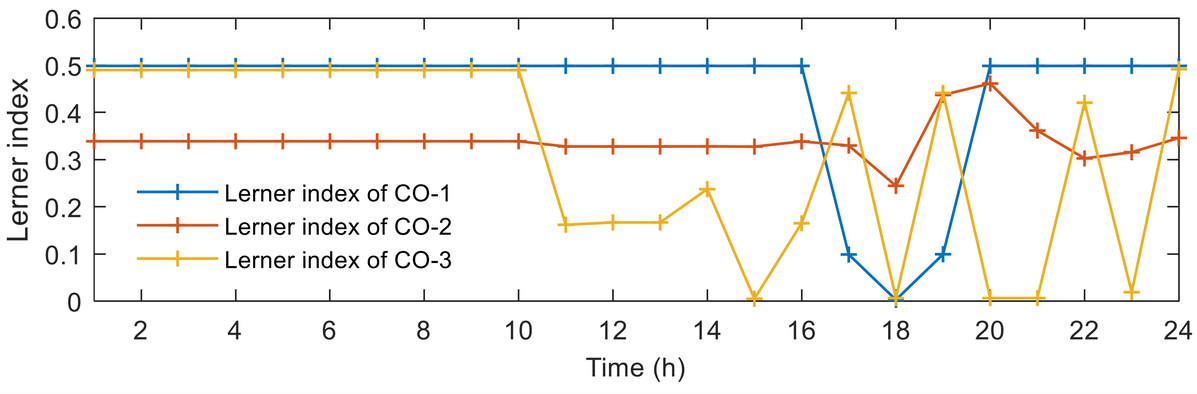
Results and Conclusion

A comparative analysis of the impacts of Perfectly Competitive Market (PCM) and Imperfectly Competitive Market (ICM) on system reserves and market clearing prices reveals several key distinctions:

- Marginal operating units in ICM tend to exercise greater market power, enabling them to strategically elevate market clearing prices.
- The clearing mechanisms employed vary substantially depending on the market structure, and the design of these mechanisms can effectively mitigate the exercise of market power.
- Under certain conditions, ICM may facilitate an increase in the system's available spinning reserve capacity.







- Case studies show that in the ICM, more units are dispatched, and energy prices are likely to be cleared as high, which will increase electricity bills of the consumers. But the reserve capacity of the entire system can potentially be increased. Future work should focus on measuring the balance between consumer bills and system reserve capacity to build an economical and safe system.