From Systematic Risk to Systemic Risk: Analysis over Day-Ahead Market Operation under High Renewable Penetration by CoVaR and Marginal CoVaR

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Background and motivation:
- Traditional power market risk studies focus on systematic risk analysis (e.g., CVaR), which only reflects the risk of a single entity.
- There is a research gap of systemic risk analysis in power market which measures the risk connections between different market participants.
- With the rapid integration of renewable energy resources, it is essentially important to identify which renewable assets contribute a higher risk to market operations.

Systematic Risk VS. Systemic Risk:
- The market operation under normal operation is a still lake if the forecast is 100% accurate. The intermittent characteristic of renewable resources is similar to throwing a stone to the lake. Then, the traditional systematic risk evaluates the momentum of the stone (size, weight, etc.), while the proposed systemic indices capture the ripple effect affecting other entities.

Contributions:
- The concept of systemic risk in energy market are clarified.
- Two indices, CoVaR and $\Delta$CoVaR, are proposed for systemic risk analysis in the power market.
- A quality index, Normalized $\Delta$CoVaR, which provide ISOs with the quality (in terms of systemic risk) of each renewable participant.
- Two systemic risk management methods are provided, depending on different market situations.
CoVaR: the risk of an entity (e.g., renewable farm) conditional on a particular event of another entity.

\[ \Pr( SC \leq CoVaR_{q}^{sys}|C(R^{i}) | C(R^{i})) = q \]

\[ \Delta CoVaR_{q}^{SC|R^{i}} = CoVaR_{q}^{SC|R^{i} = VaR_{q}^{R^{i}}} - CoVaR_{q}^{SC|R^{i} = Median^{R^{i}}} \]

Normalized \( \Delta CoVaR \): the proportion of the percentile \( \Delta CoVaR \) and the share of a renewable’s capacity

\[ q^{P} = \frac{\Delta CoVaR_{q}^{SC|R^{i}} \sum_{i} p^{i}}{VaR_{q}^{(SC - SC_{avg})}} \leq threshold \]
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(a) IEEE 118-bus with 8 regions

(b) cumulative probability of renewables based on historical data

(c) Systemic risk network

(d) Asset decomposition

(e) Capacity reduction
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