Chance-constrained pre-contingency joint self-scheduling of energy and reserve in a VPP

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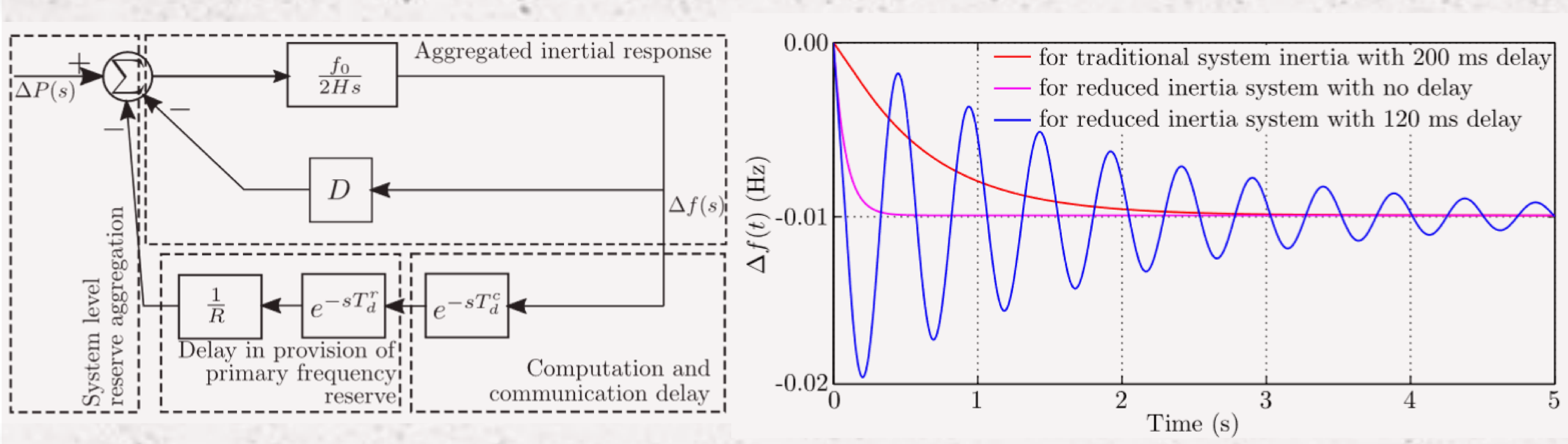
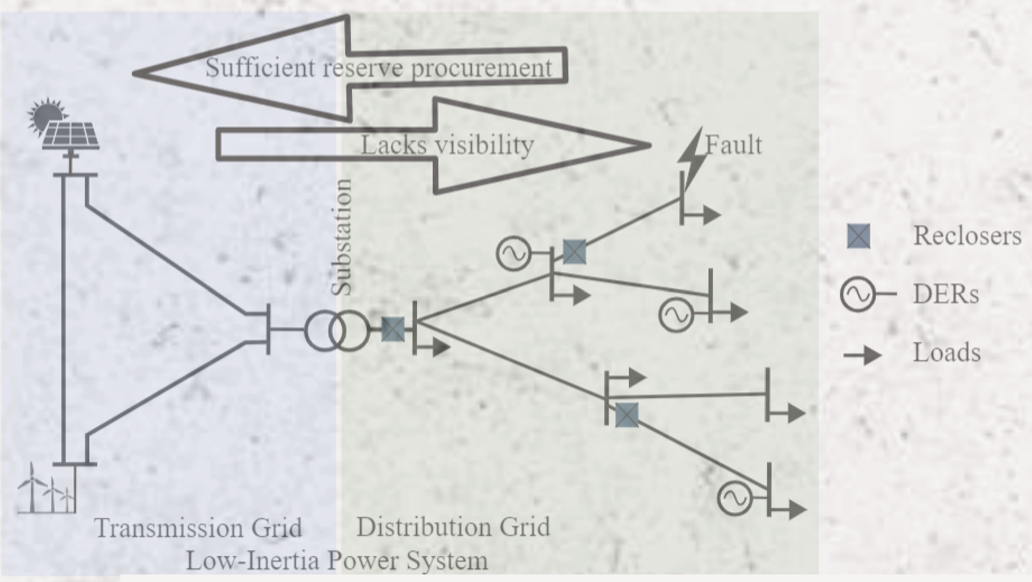
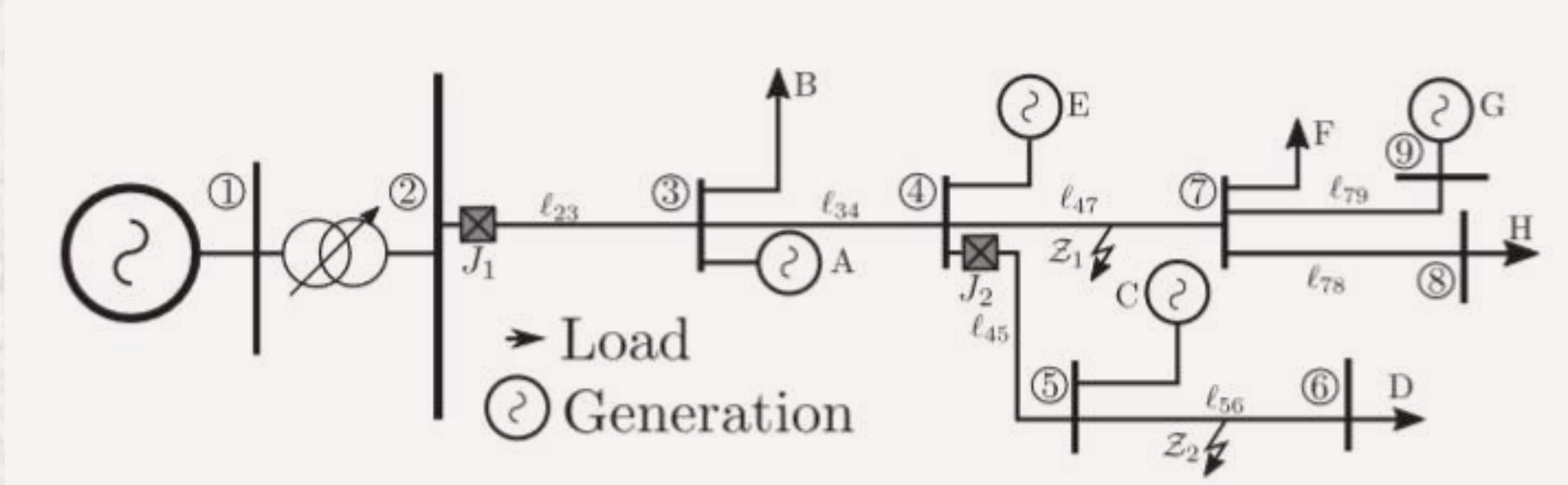
Motivation



- Increasing delay can be problematic, especially in a low-inertia system



- ISOs lack visibility inside distribution network
- How much reserve to procure?
- Who should procure?



- Load generation imbalances are location-dependent and dependent on the schedule
- Local generators if providing reserve can be outaged as well

Chance Constraint

- How much reserve is needed (load generation imbalance)?

$$P_{\xi,t}^{Imb} = \sum_{\forall q \in \mathcal{I}} \left(P_{q,t}^{L} - P_{q,t}^{G}\right) \mathrm{A}_{\xi,q}$$

- How much reserve is available?

$$E_{\xi,t}^{Imb} = \underbrace{\sum_{\forall q \in \mathcal{I}} E_{q,t}^{tot} \left(1 - \mathrm{A}_{\xi,q}\right)}_{\text{Local reserve}} + \underbrace{E_{0,t}^{BR}}_{\text{Market-based reserve}}$$

- Reserve sufficiency

$$\mathbb{P}\left(\sum_{\forall \xi \in \mathcal{N}} \left(P_{\xi,t}^{Imb} - E_{\xi,t}^{Imb}\right) \mathbb{1}_{\mathcal{N}}(\xi) \leq 0\right) \geq \kappa; \quad \forall t$$

$$\mathbb{P}\left(\sum_{\forall \xi \in \mathcal{N}} \left(-P_{\xi,t}^{Imb} - E_{\xi,t}^{Imb}\right) \mathbb{1}_{\mathcal{N}}(\xi) \leq 0\right) \geq \kappa; \quad \forall t$$

Or, $\mathrm{VaR} \leq 0$

Formulation

$$\mathrm{VaR}_{\kappa}\left(\sum_{\forall \xi \in \mathcal{N}} (P_{\xi,t}^{Imb} - E_{\xi,t}^{Imb}) \mathbb{1}_{\mathcal{N}}(\xi)\right) \leq \mathrm{CVaR}_{\kappa}\left(\sum_{\forall \xi \in \mathcal{N}} (P_{\xi,t}^{Imb} - E_{\xi,t}^{Imb}) \mathbb{1}_{\mathcal{N}}(\xi)\right) \leq 0$$

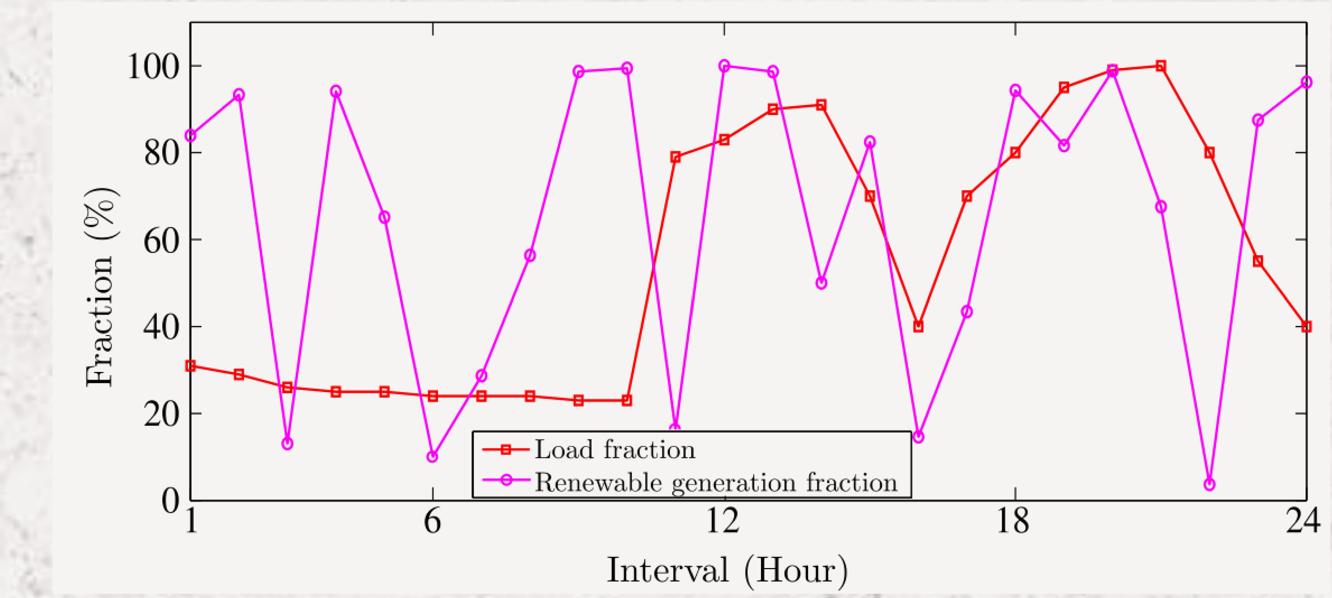
- So, we can use CVaR interchangeably with VaR

$$\Xi + \frac{1}{1-\kappa} \sum_{\forall \xi} \mathbb{P}_{\xi} \beta_{\xi} \leq 0$$

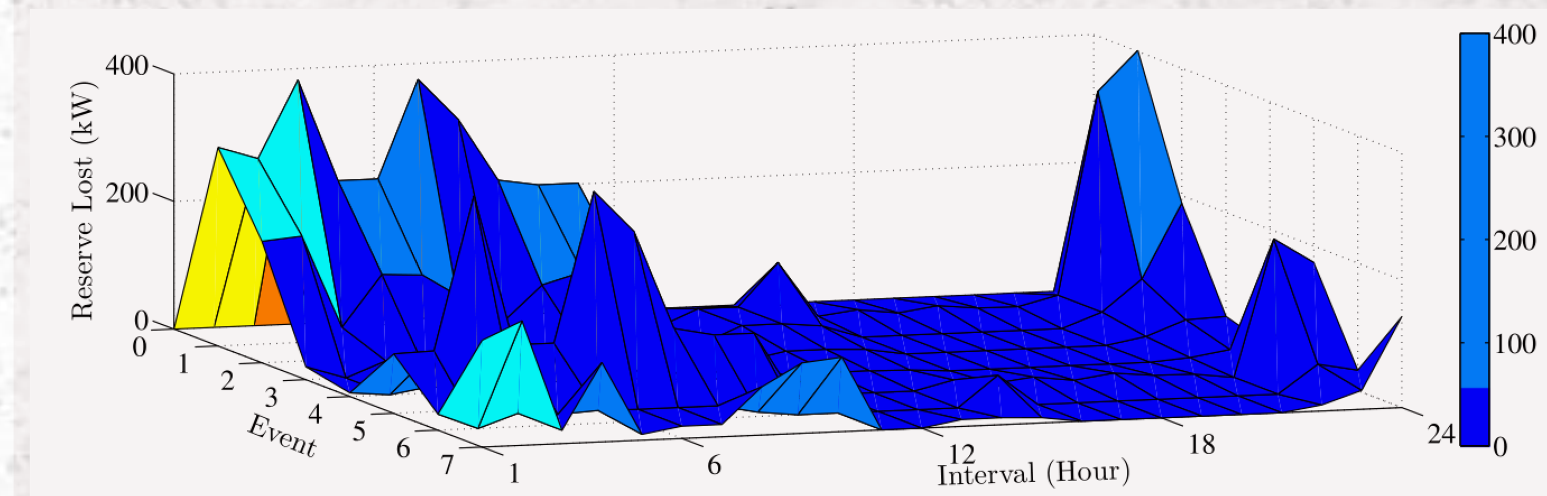
$$\mathrm{x}_{\xi} - \Xi - \beta_{\xi} \leq 0; \beta_{\xi} \geq 0; \forall \xi$$

Our problem formulation is convex!

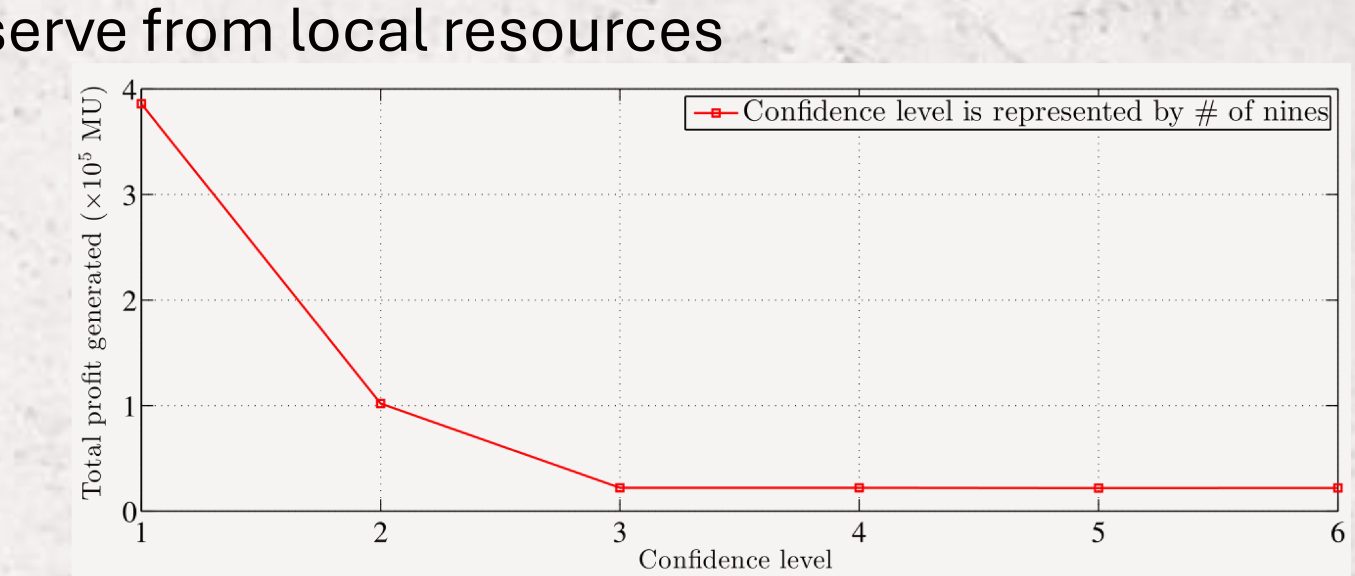
Example



Example renewable generation / load pattern

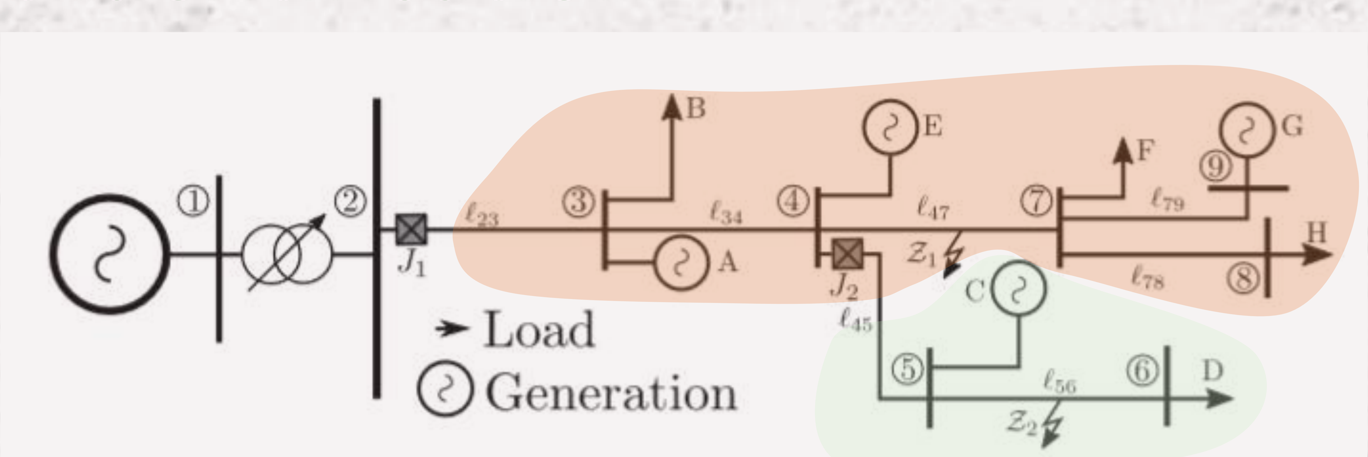


Depending upon the prices, it is worthy to procure reserve from local resources



Reserve can be procured locally under lower confidence bound

Event Identification



- Probability that none of the event occurs:

$$\mathbb{P}_{0,t} = \prod_{\forall \xi} e^{-\lambda_{\xi,t} k_t} = e^{-\sum_{\forall \xi} \lambda_{\xi,t} k_t} \approx 1 - \sum_{\forall \xi} \lambda_{\xi,t} k_t$$

- Probability that event u occurs:

$$\mathbb{P}_{\mathrm{u},t} = e^{-\sum_{\forall \xi, \mathrm{u} \neq \xi} \lambda_{\xi,t} k_t} \left(1 - e^{-\lambda_{\mathrm{u},t} k_t}\right) \approx \left(1 - \sum_{\forall \xi, \mathrm{u} \neq \xi} \lambda_{\xi,t} k_t\right) \lambda_{\mathrm{u},t} k_t \approx \lambda_{\mathrm{u},t} k_t$$

Discussion

- We need a risk-constrained approach to FAR provisioning due to the stochastic nature of temporary faults
- Current market structure do not account for the impact of these events
- Reserve requirements can influence the local energy schedule and raise energy costs
- The confidence level of the chance-constraint can significantly impact the overall profitability
- Effectiveness of DER integration depends significantly on policy and incentive structures; the market operators should come up with innovative structures to manage the impact of future grid events

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Link to articles: