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SecuLEx

A Secure Limit Exchange Market for Dynamic Operating Envelopes

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Motivation

- Networks were sized for static worst-case demand and one-directional flows
- DERs break that assumption: flows now reverse and vary hour to hour
- Consequences: voltage violations, congestion, demand mismatch
- Even oversized grids fail to integrate new DERs efficiently

Existing approaches, and what they miss

Approach	What it does	What it misses
Active network management (ANM)	Curtails or reschedules DERs in real time.	Poor scalability and observability.
Dynamic operating envelopes (DOEs)	Ensure network security	Fixed and non-transferable
Local energy markets (LEM)	Trade energy (kWh)	Not the network capacity (kW) itself.

SecuLEx makes the limits tradeable, while keeping the network secure.

SecuLEx: allocate fairly, then trade

1. **Allocate**

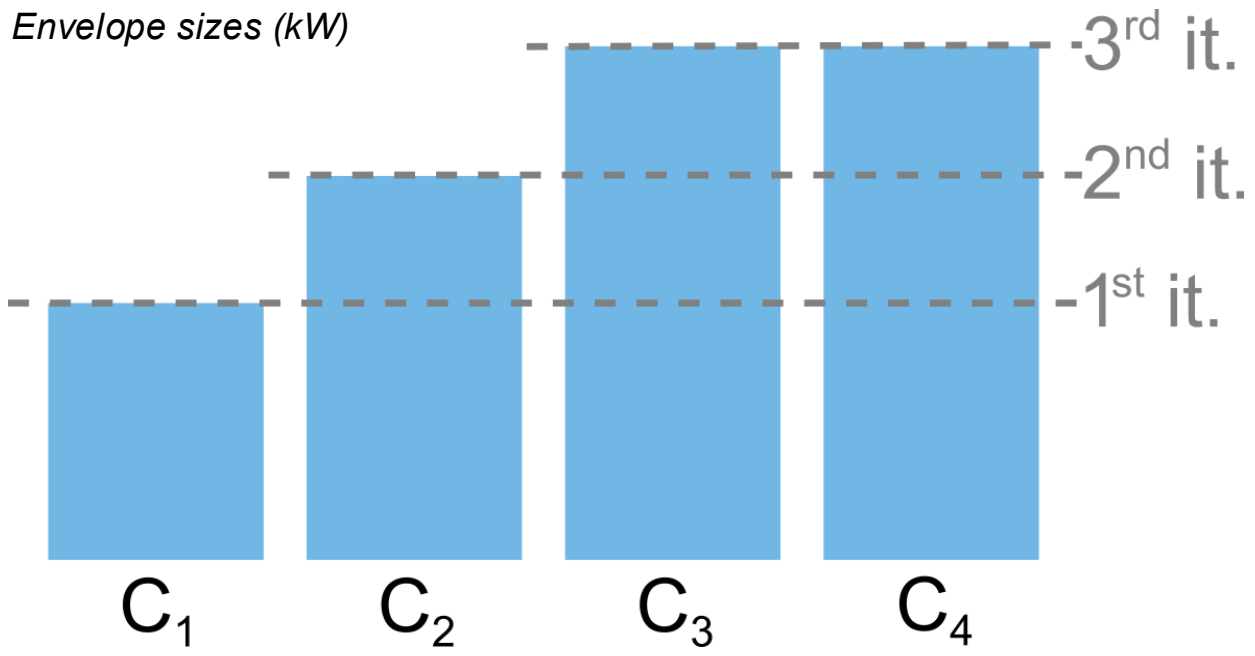
- The DSO assigns initial DOEs to all customers
- Uses a lexicographic max-min optimization program
- Guarantees fairness and network security

2. **Trade**

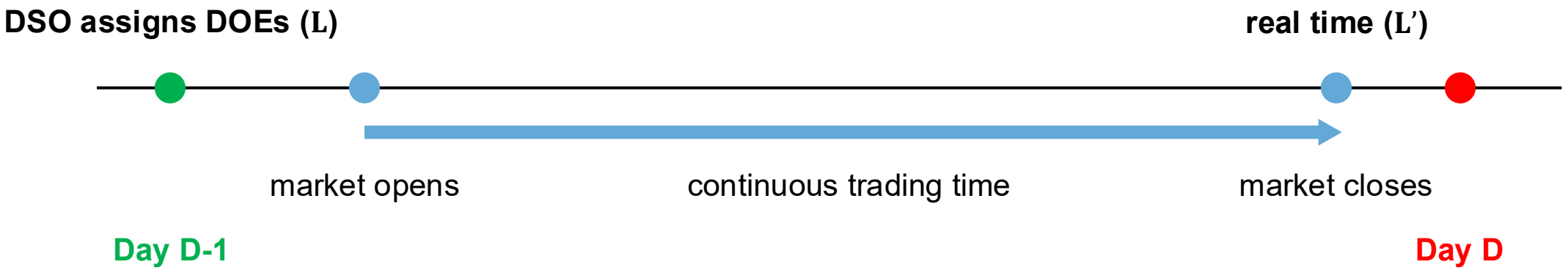
- A continuous market allows customers to buy and sell portions of their envelopes
- Matches limits to actual real-time needs (day-ahead up to real-time)
- Network security is verified before every cleared trade

DOEs and security

- Each customer receives DOEs:
  - $\mathbf{L_c} = [\underline{P}_c, \overline{P}_c] \ \forall c \in \mathcal{C}$
- Security is gurantee when limits are respected
- Initial allocation by lexicographic max-min: maximize the smallest envelope first, fix it, repeat.



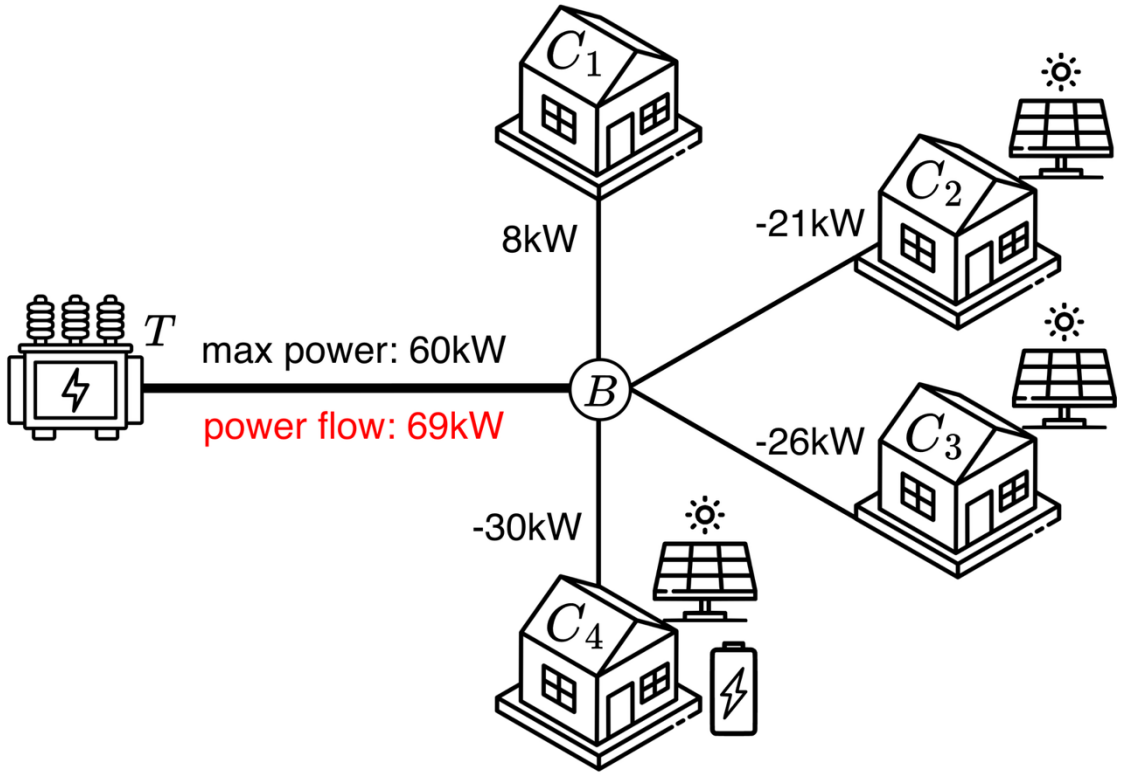
A continuous market for limits



Orders. Buy/sell a portion of the lower/upper limit for a given price and a specific time

Clearing. Maximize social welfare ($\sum_{b\in\mathcal{B}} \pi_b a_b - \sum_{s\in\mathcal{S}} \pi_s a_s$), subject to the security check on the updated limits $\mathbf{L}$'. A linear program under the DC approximation

Illustrative example



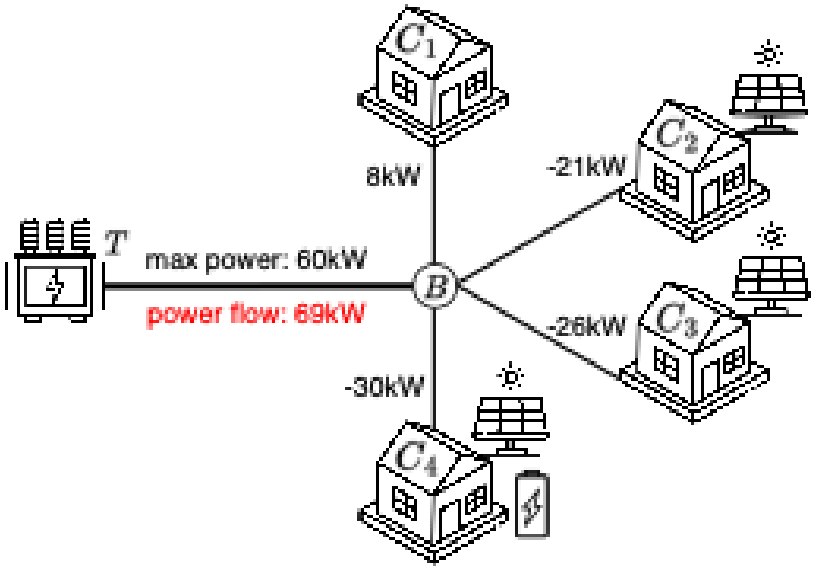
Expected midday positions

Cust	Type	Net (kW)	Buy (€/kWh)	Feed-in (€/kWh)
C_1	load	+8	0.15	—
C_2	PV	−21	0.16	0.06
C_3	PV	−26	0.15	0.04
C_4	PV + batt.	−30	0.15	0.02

Four ways to handle the congestion

- **No control.** 9kW overload. The network is insecure
- **Centralized ANM.** DSO curtail 9kW in real time (equally over C_2-C_4); opportunity loss 0.36€. No access to customer batteries
- **DOEs.** Fixed day-ahead DOEs. 7 to 17kW curtailed depending on C_4's choice (0.30-0.50€)
- **SecuLEx.** Customers trade limits to use their flexibility. Only 1kW curtailed

SecuLEx



Updated lower limits

- **C_2:** −20kW → −21kW
- **C_3:** −20kW → −25kW
- **C_4:** −20kW → −14kW

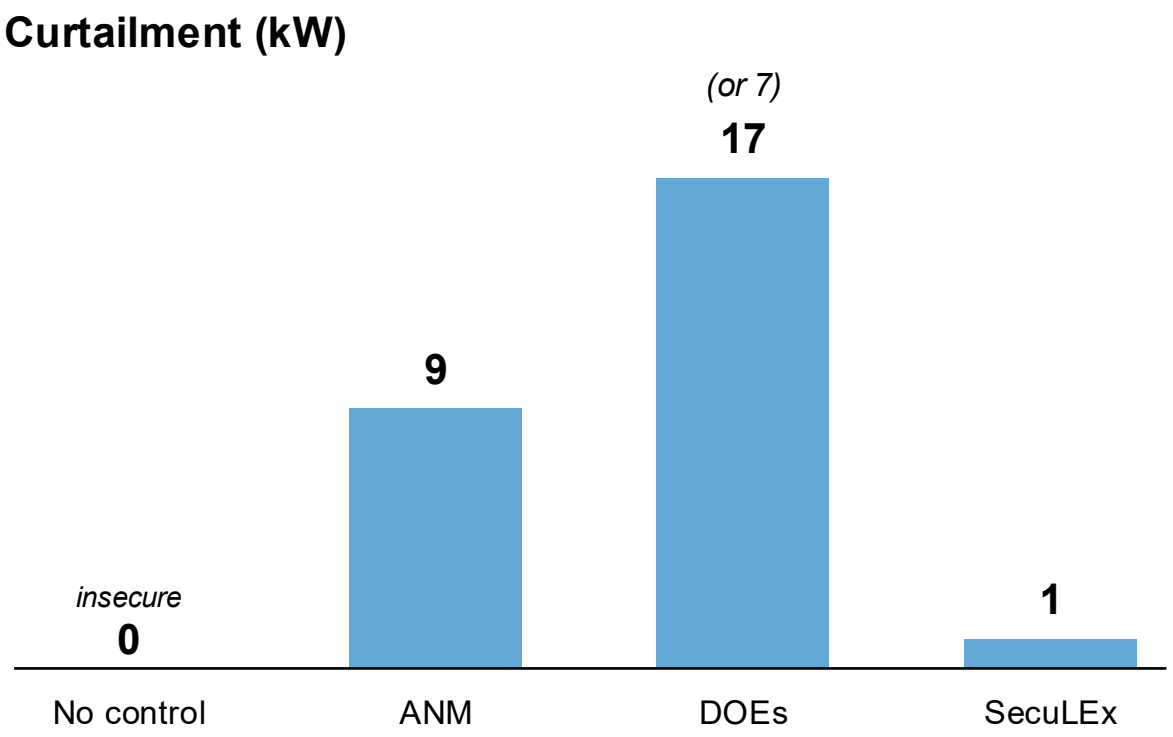
Order book

Cust.	Type	Bound	Price (€/kW)	Qty (kW)
C_2	buy	lower	0.03	1
C_3	buy	lower	0.02	6
C_4	sell	lower	0.02	6

Pay-as-bid:

- **C_2:** pays 0.03€
- **C_3:** pays 0.10€
- **C_4:** receives 0.12€
- **Social welfare:** 0.01€ (goes to the DSO)

Summary results



Metric	No ctrl	ANM	DOEs	SecuLEx
Curtailment (kW)	0	9	17 (or 7)	**1**
Renewable use (%)	100	87	76 (90)	**99**
Security violation	Yes	No	No	**No**
Incentivizes flex.	No	No	Partial	**Yes**
Social welfare (€)	–	–	–	**0.01**

Conclusions

- **Fair and flexible**: an egalitarian allocation gives a secure starting point; a market reallocates it to real need

- **Security is cheap**: under radial + DC, verification reduces to two boundary checks; allocation and clearing are LPs

- **Value without central control**: lower curtailment and higher renewable use, with no real-time central operation.

Thank you

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