

Introduction

The rapid integration of photovoltaic panels (PVs), electric vehicles (EVs), and batteries creates new operational challenges in the networks, such as:

- Reverse active and reactive power flows.
- Congestion (overloaded transformers and lines).
- Voltage limit violations.
- Inefficient renewable energy curtailment.

Motivation

Traditional methods either fail to guarantee **security** and **fairness** or are **complex**. Therefore, there is a need for a new **operational paradigm** for **better coordination** of the network from TSO to customers.

A comparison of approaches is given below:

Approach	Security	Fairness	Efficiency
Fit & Forget	✗	✗	✗
ANM	✓	✓	✓
DOEs	✓	✓	✓
DOEs + Market	✓	✓	✓

Research question

How can **security, fairness and flexibility** be guaranteed from transmission systems to individual consumers?

Solution

We propose a hierarchical, two-level framework where:

- **Level 1: TSO-DSO Coordination**
TSO and DSOs exchange voltage and power limits to operate independently but securely.
- **Level 2: Customer-Level Market**
A continuous market allows end-users to trade their DOEs, allocating flexibility.

Methodology

TSO-DSO coordination

- We consider the grid as connected subgraphs managed independently by TSOs or DSOs.
- To ensure global security, they exchange limits at their connection points:
 - DSOs and the TSO agree on contractual **voltage limits** at their interface.
 - The TSO provides **power limits**, called dynamic operating envelopes (DOEs) to DSOs.
- A robust optimization problem outputs the best possible DOEs that keep the network secure under the voltage guarantees.
 - The DSO allocates DOEs fairly by maximizing the smallest envelope first.

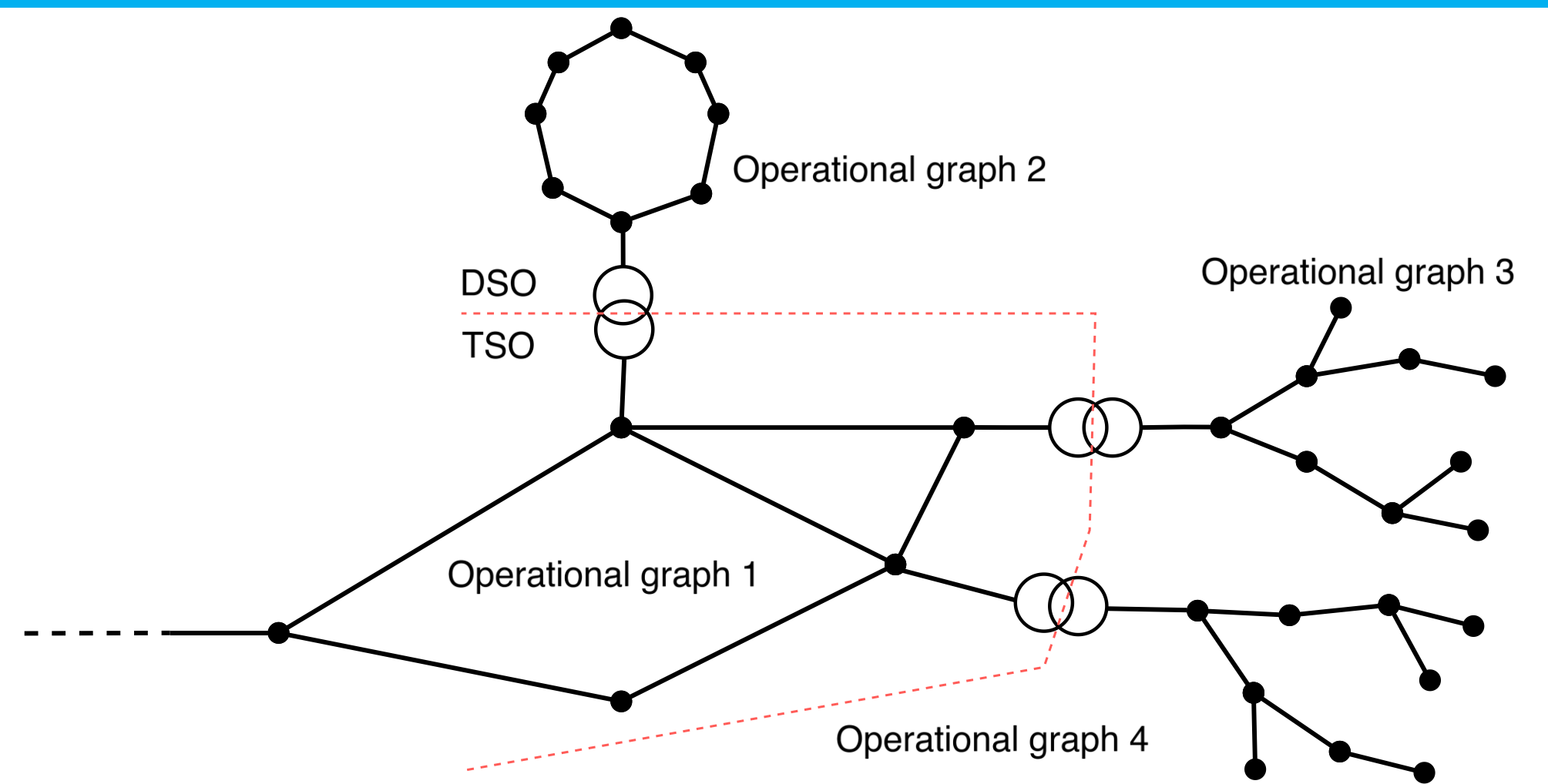


Fig 1. Operational graph separation of TSO-DSO networks.

DOEs exchange through market

- Transform DOEs into **tradable assets**.
- Customers submit **buy and sell orders** of their injection/withdrawal DOEs.
- An optimization algorithm matches orders to maximize **social welfare**, such that only secured trades are allowed.

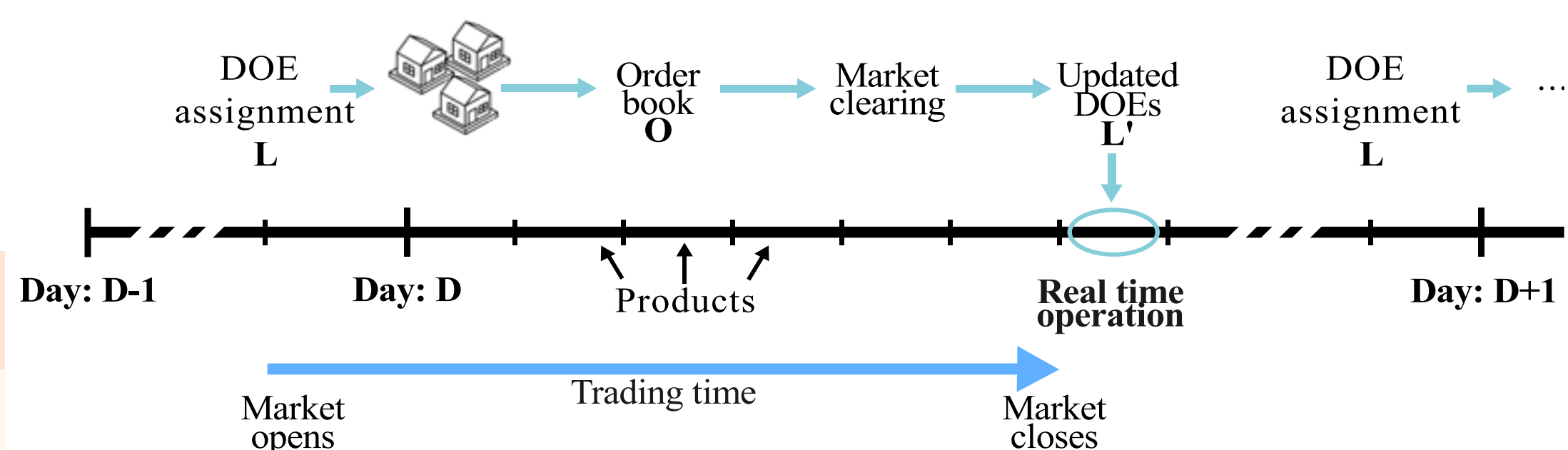


Fig 2. Timeline for DOE assignment and market

Conclusion

Contributions

Decoupled TSO-DSO Operation: a novel paradigm for secure, decoupled grid operation through bilateral voltage and power limits .

Security-Guaranteed DOE Trading: a market mechanism that transforms operating envelopes into tradable assets while embedding network security directly into the exchange process .

DOEs Library: the implementation of an open-source library to solve the DOE allocation problems depending on the user's network characteristics.

Future works

- **Scalability Test:** apply the algorithms on large-scale electrical networks.
- **Operational actions:** extend the operational actions, including topology reconfiguration, etc.