Analyzing the Role of the DSO in Electricity Trading of VPPs via a Stackelberg Game Model

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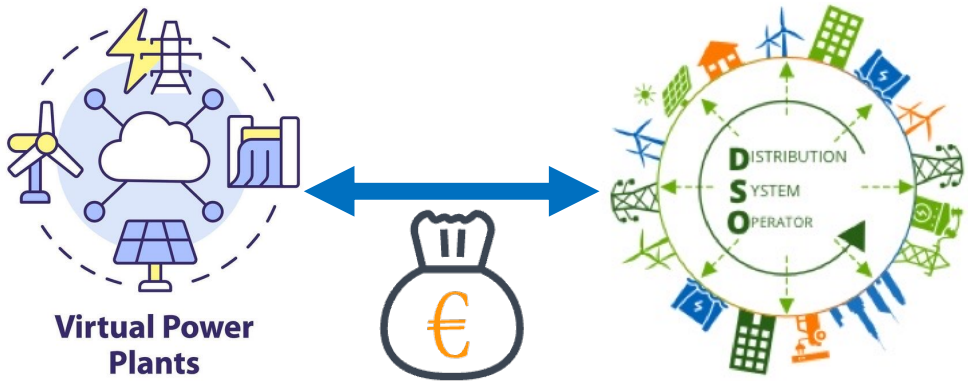
Section I

BACKGROUND

Background

- VPPs: emerging players in electricity markets
- DSO: shifting to an active market participant
- Profit-oriented operation: min costs & max profits



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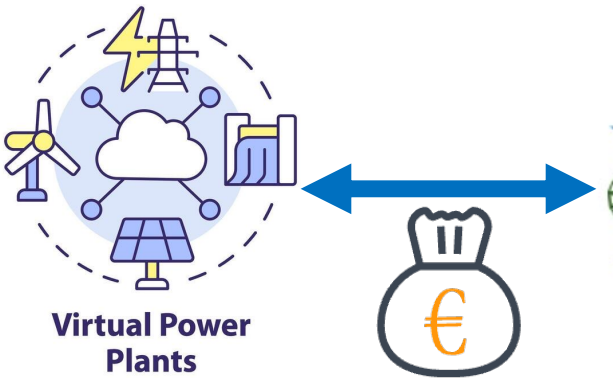


- How do they affect the market
- What can we learn from this

Section II

COMPONENTS OF VPP

Components of VPP

Micro Turbine (MT)

Battery Storage (BS)

Wind Turbine (WT)

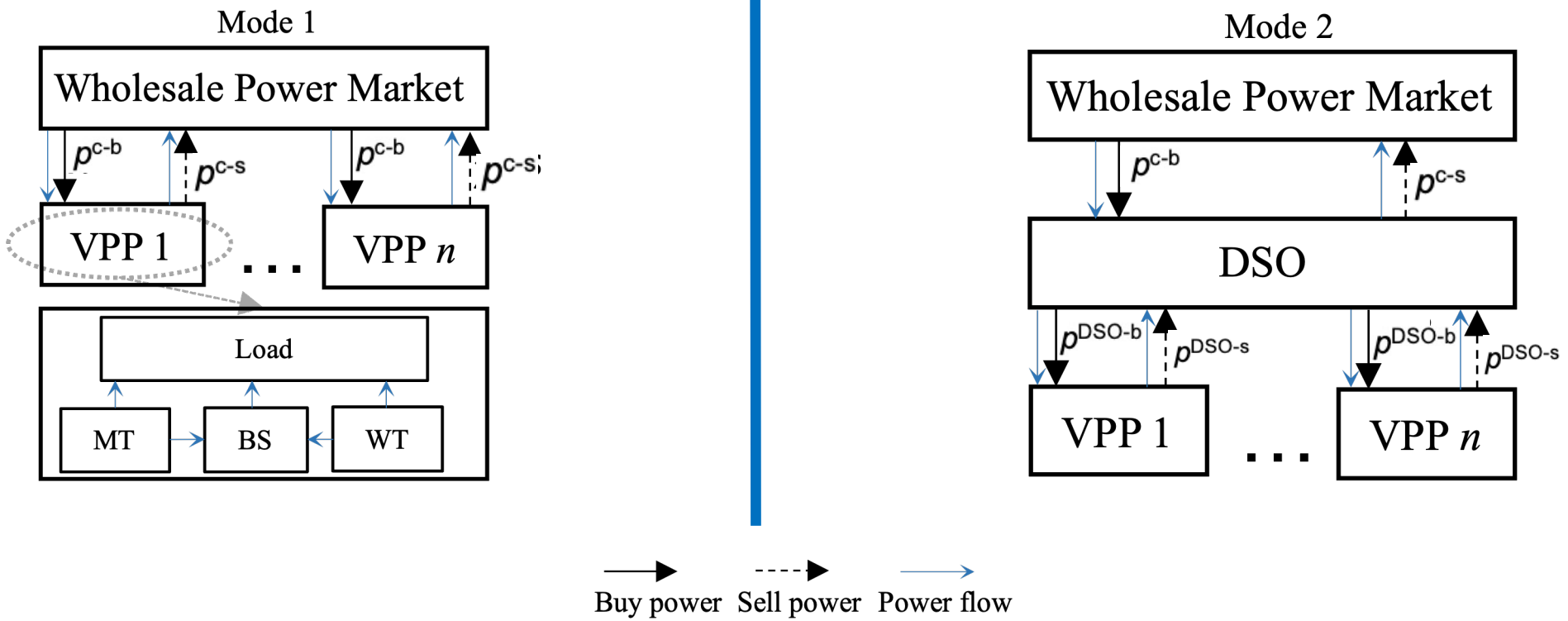
System load

VPP:
purchase or sell power

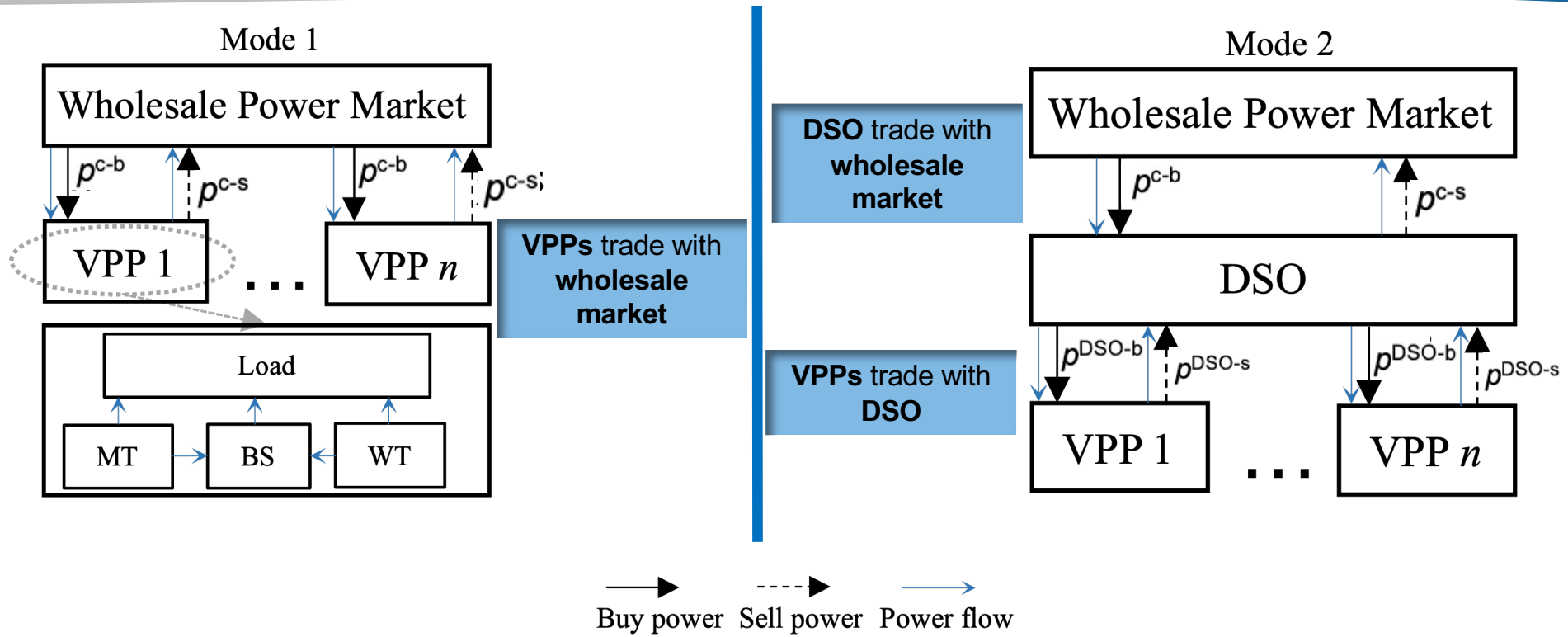
Section III

MARKET STRUCTURES

Market structures



Market structures



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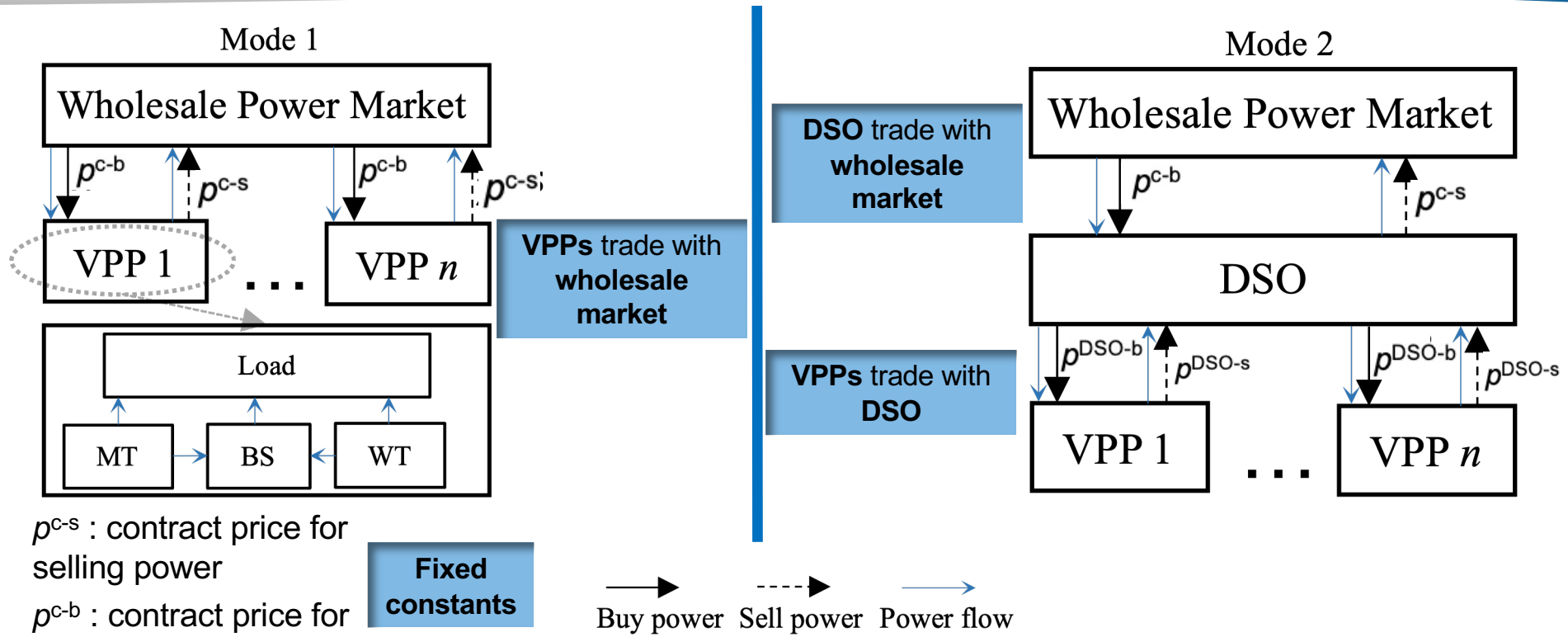


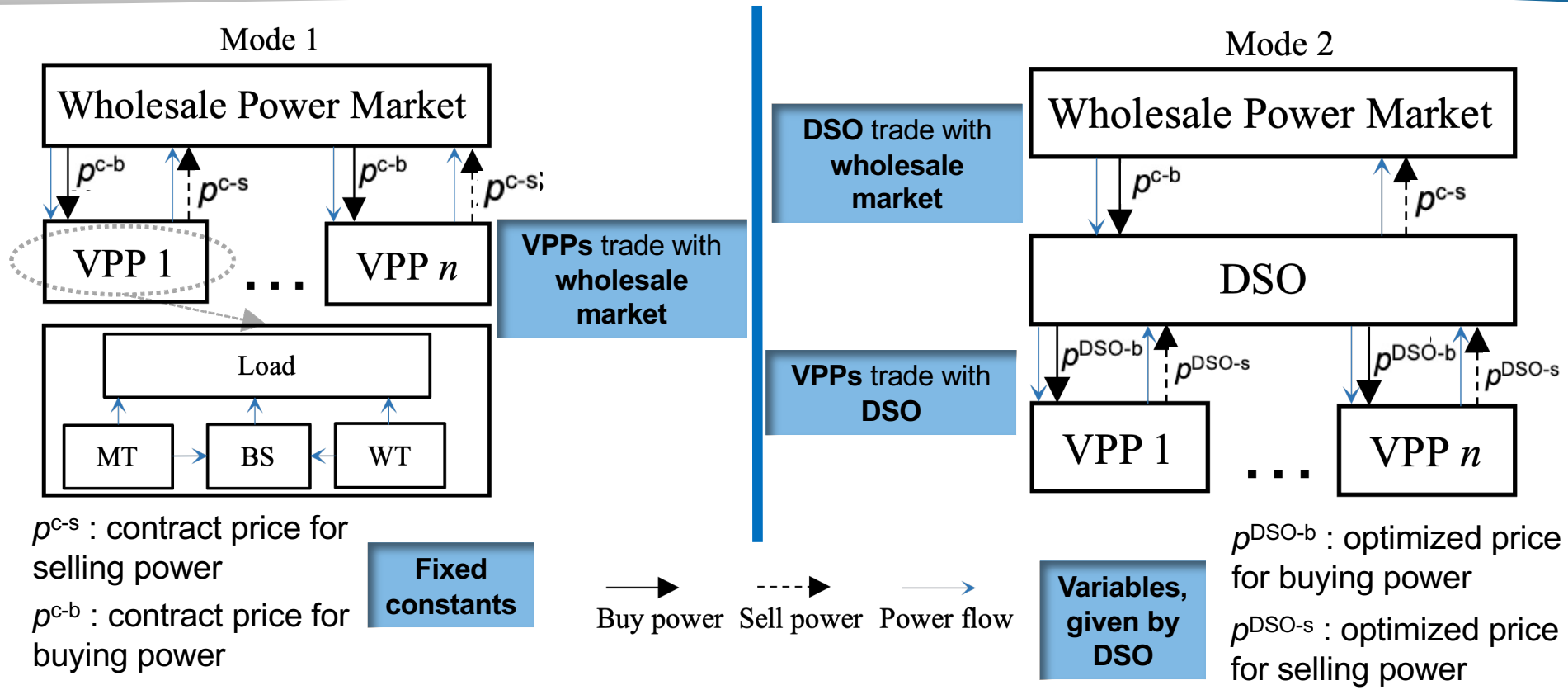
$p^{c\text{-}s}$: contract price for selling power

$p^{c\text{-}b}$: contract price for buying power

Fixed constants

Buy power Sell power Power flow

Market structures



$p^{c\text{-}s}$: contract price for selling power

$p^{c\text{-}b}$: contract price for buying power

Fixed constants

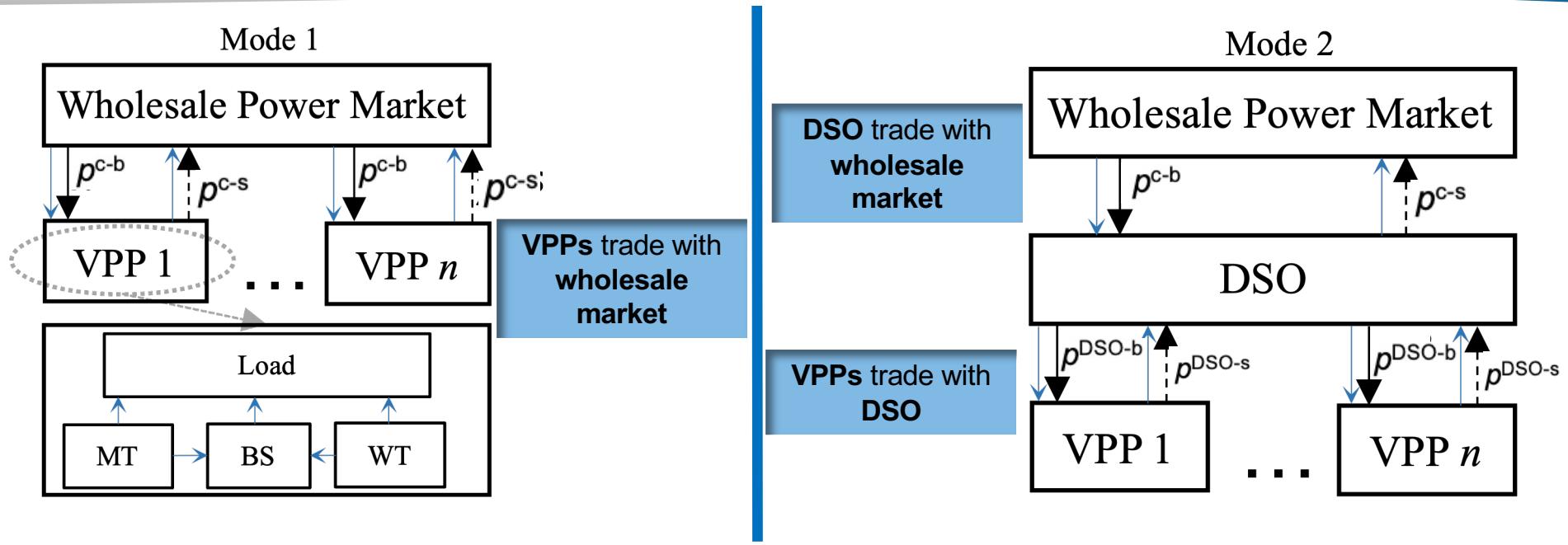
Buy power | Sell power | Power flow

Variables, given by DSO

$p^{DSO\text{-}b}$: optimized price for buying power

$p^{DSO\text{-}s}$: optimized price for selling power

Market structures



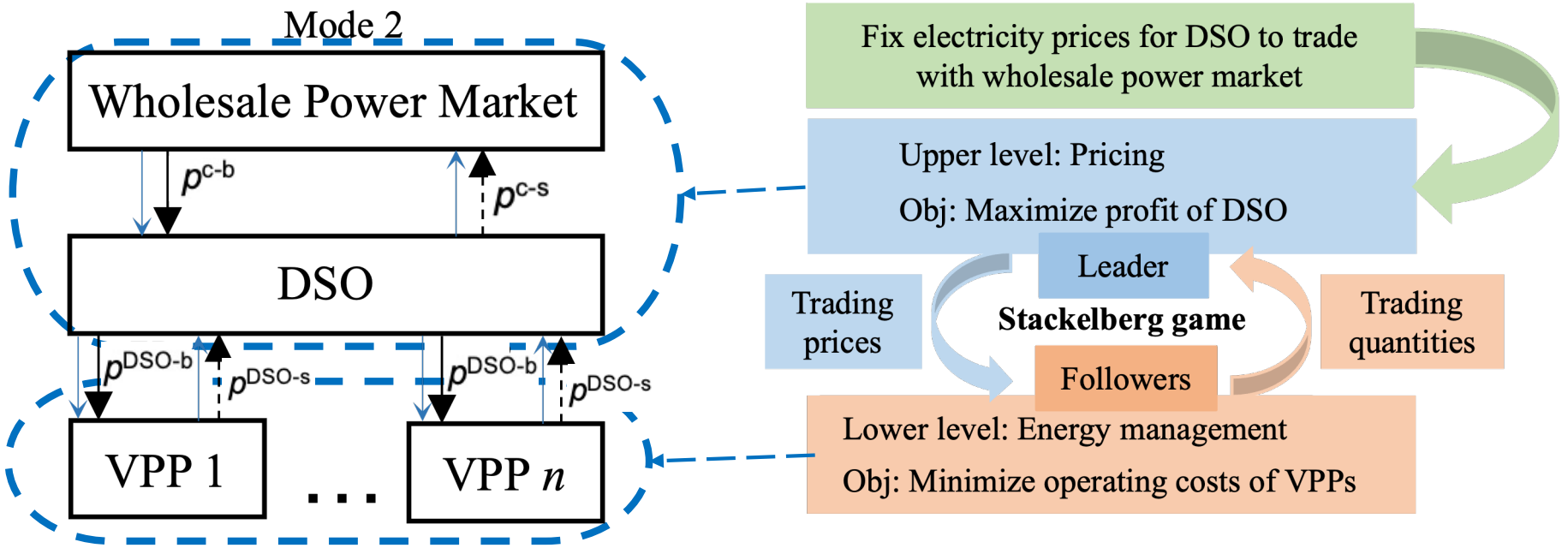
- For VPPs: trading prices change
- For wholesale market: trading volumes change

→ Various dispatch and cash flows

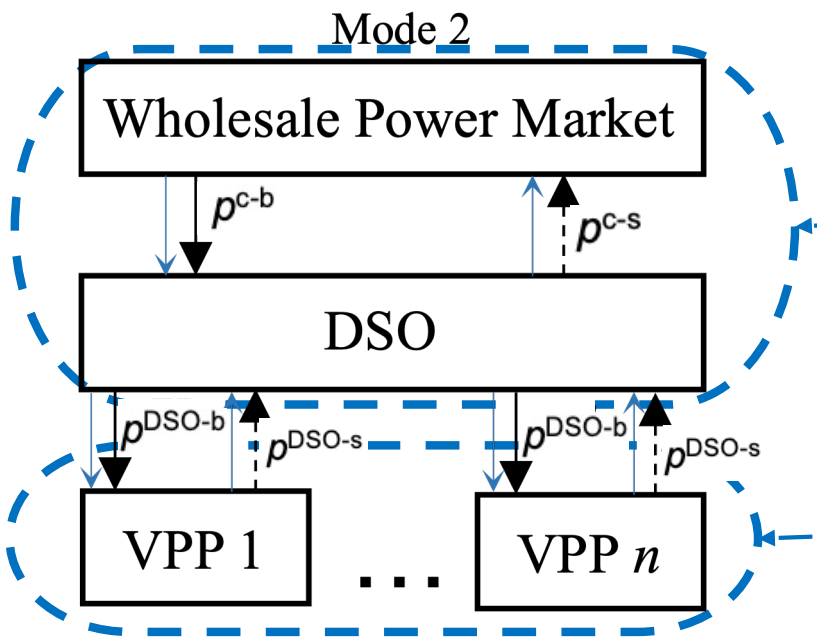
Section IV

STACKELBERG GAME BETWEEN DSO AND VPPS

Stackelberg game between DSO and VPPs



Stackelberg game between DSO and VPPs



Fix electricity prices for DSO to trade with wholesale power market

Upper level: Pricing

Obj: Maximize profit of DSO

Leader

Trading prices

Stackelberg game

Trading quantities

Followers

Lower level: Energy management

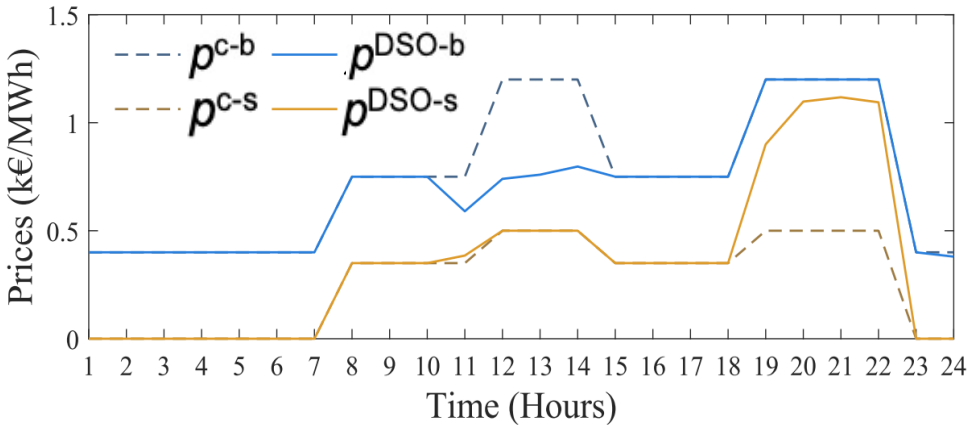
Obj: Minimize operating costs of VPPs

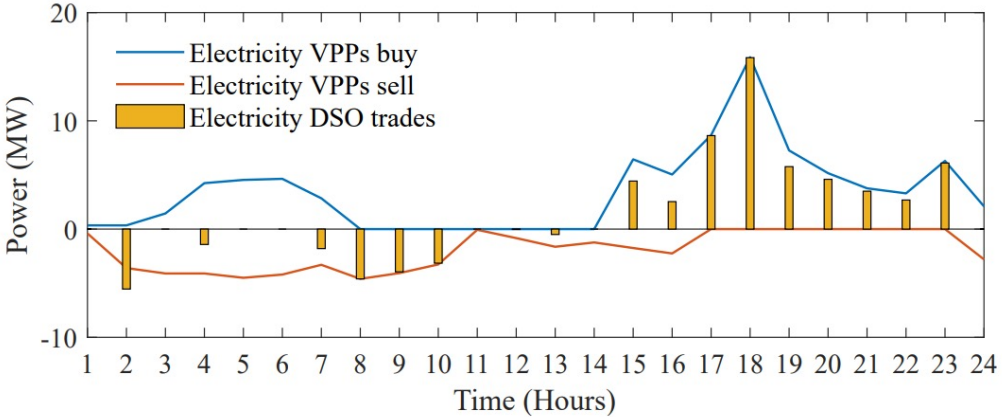
Bilevel model

Section V

RESULTS

Results





$p^{c\text{-}s}$, $p^{c\text{-}b}$: contract prices
$p^{DSO\text{-}b}$, $p^{DSO\text{-}s}$: prices given by DSO

Trading volumes of whole market

VPPs prefer to trade with the DSO

Net outflow power, from wholesale market, is reduced

Results

COSTS AND PROFITS OF STAKEHOLDERS IN TWO MODES

Stakeholders	Mode 1 (k€)	Mode 2 (k€)
VPP_1	−3.947	−3.942
VPP_2	−0.918	−0.891
VPP_3	−3.587	−3.559
DSO	—	1.134
Wholesale market	5.370	4.152

Lost profits in wholesale market = DSO profits + VPPs reduced costs

Profits of wholesale market means: flow-into cash minus flow-out cash

Section VI

LEARNING

Learning

1. VPP can dispatch flexible sources and trade strategically based on prices.
2. DSO can profit from acting as a middleman.
3. The agent's operating strategy does not fully guarantee the profits of stakeholders in the wholesale market.
4. This reflects the significance of improving market regulation.

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Thanks for your attention !

GitHub

- https://github.com/pwang30/Code_of_bilevel_DSO_VPPs
- https://pwang30.github.io/

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