Leveraging Consumers' Flexibility for the Provision of Ancillary Services

G. De Zotti*, H. Madsen*, A. Pourmousavi**, H. Binder***

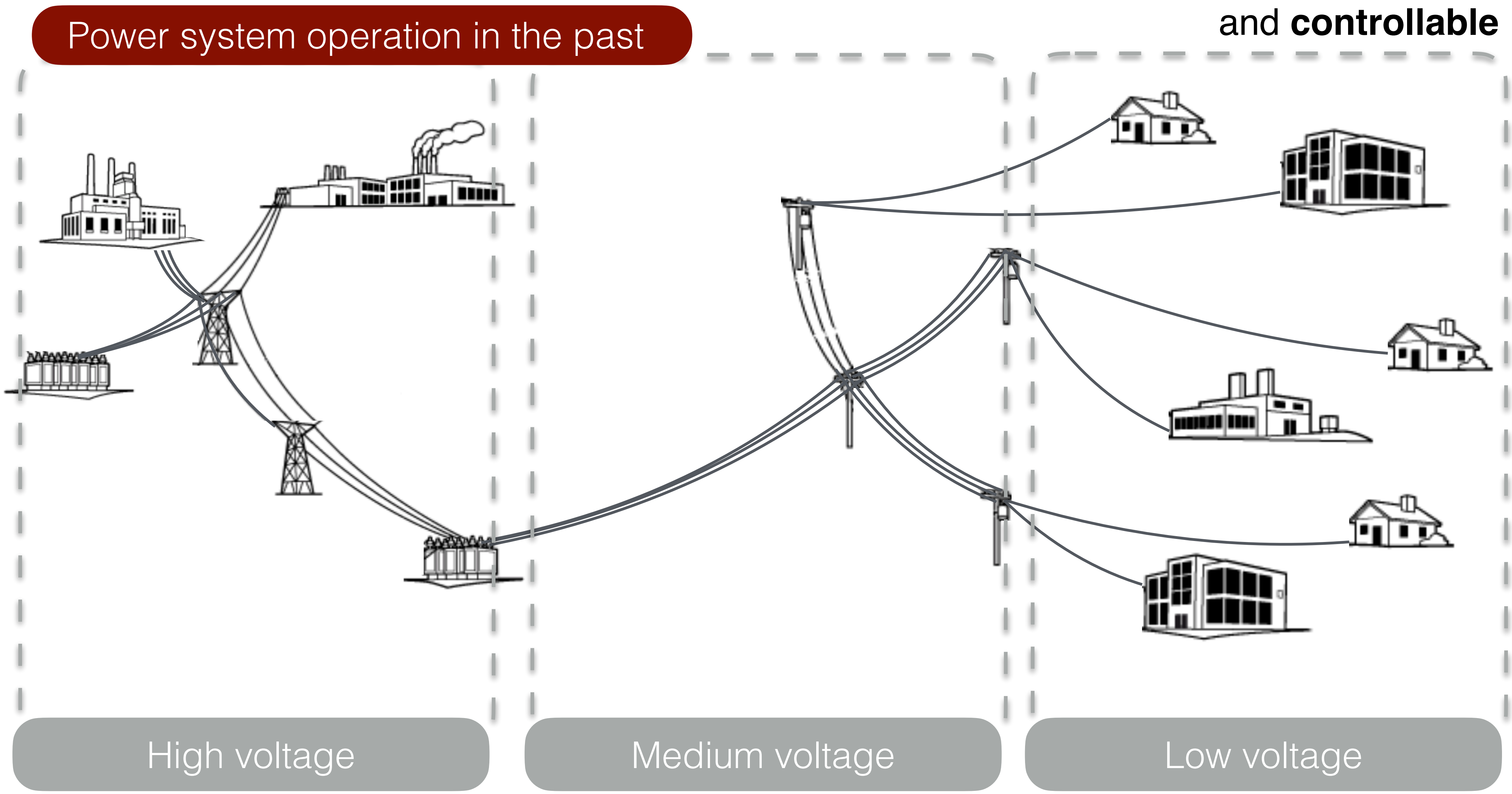
* Technical University of Denmark
** The University of Adelaide
***Energinet

Agenda

- Introduction
- Innovative solution for unlocking consumers’ flexibility potential: Ancillary Services 4.0
- Modelling of the Ancillary Services 4.0 approach
- Results
- Concluding remarks

Introduction
Context and motivation

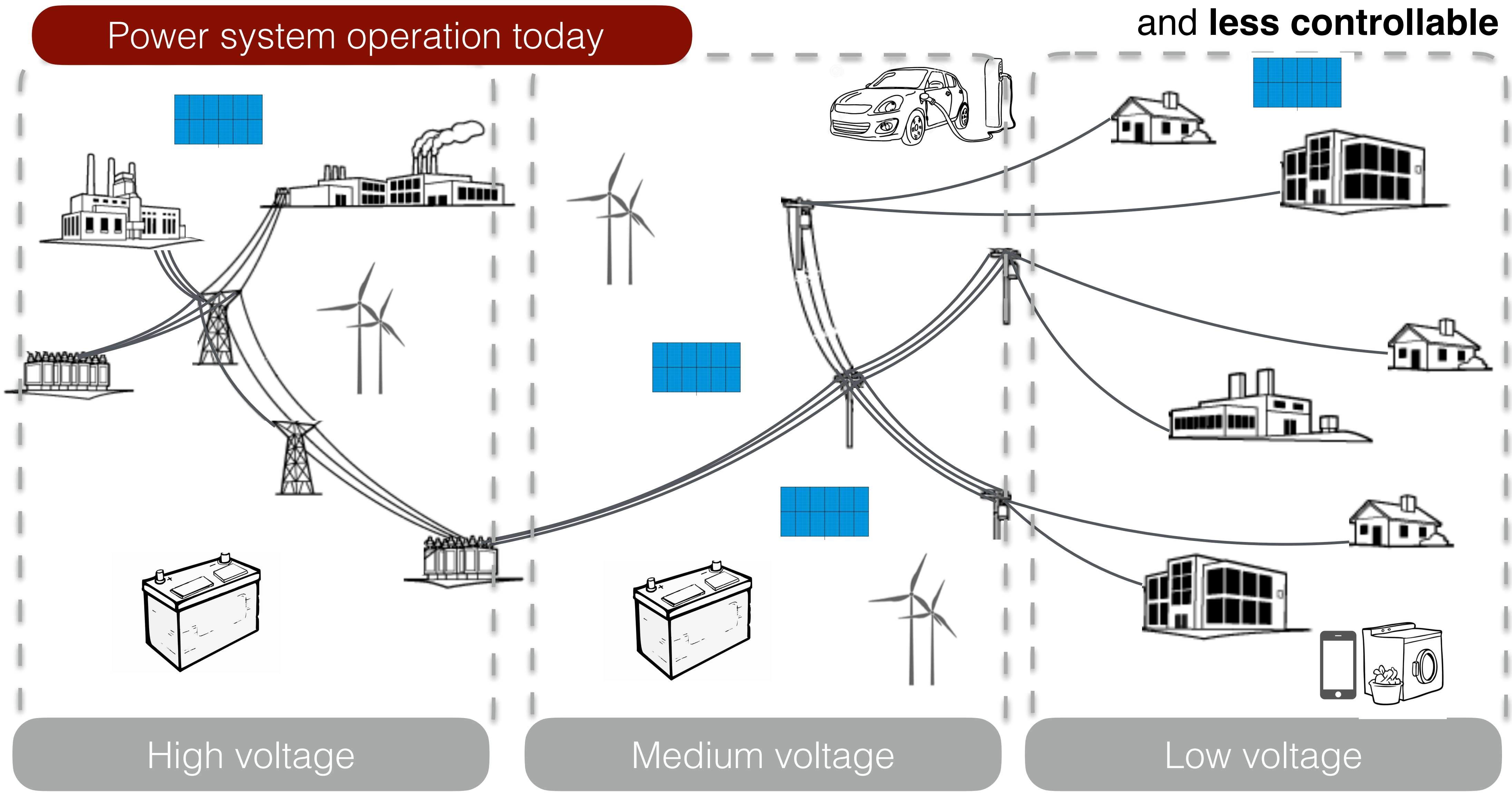
Operation **almost predictable** and **controllable**



Conventional generation units
Reactive and **passive** consumers

Introduction
Context and motivation

Operation **more stochastic**
and **less controllable**



Intermittent **renewable** generation units
Active and **dynamic** consumers

Introduction

Context and motivation

Challenges for the power system operation

Increasing complexity

Stochasticity
Non linearity
Dynamics

Higher need of stability

Higher demand of **ancillary services** (AS)

Uncertainty of AS provision

Conventional generation units operating under rated capacity

Retirement of conventional generation units

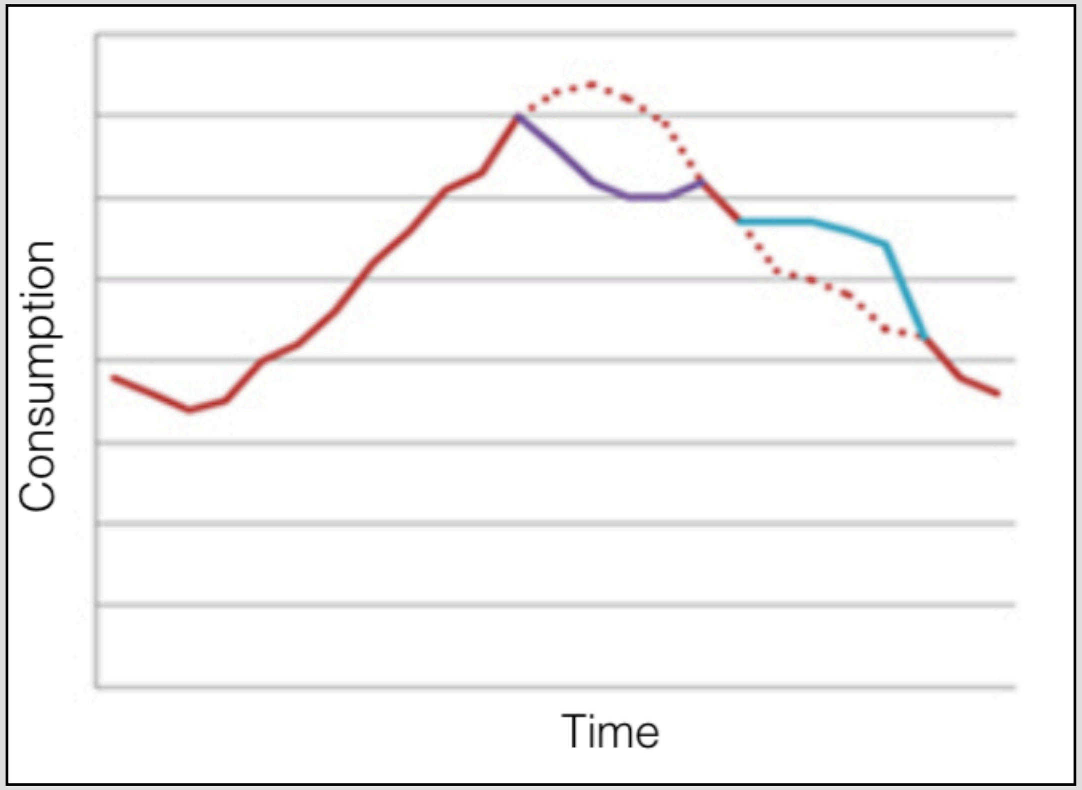
International climate targets

Denmark:
2030: 70% CO2 reduction
2050: CO2 neutrality

Introduction
Key concepts in power systems

Demand response programs

In demand response (DR), consumers alter their consumption according to the necessity of the grid.



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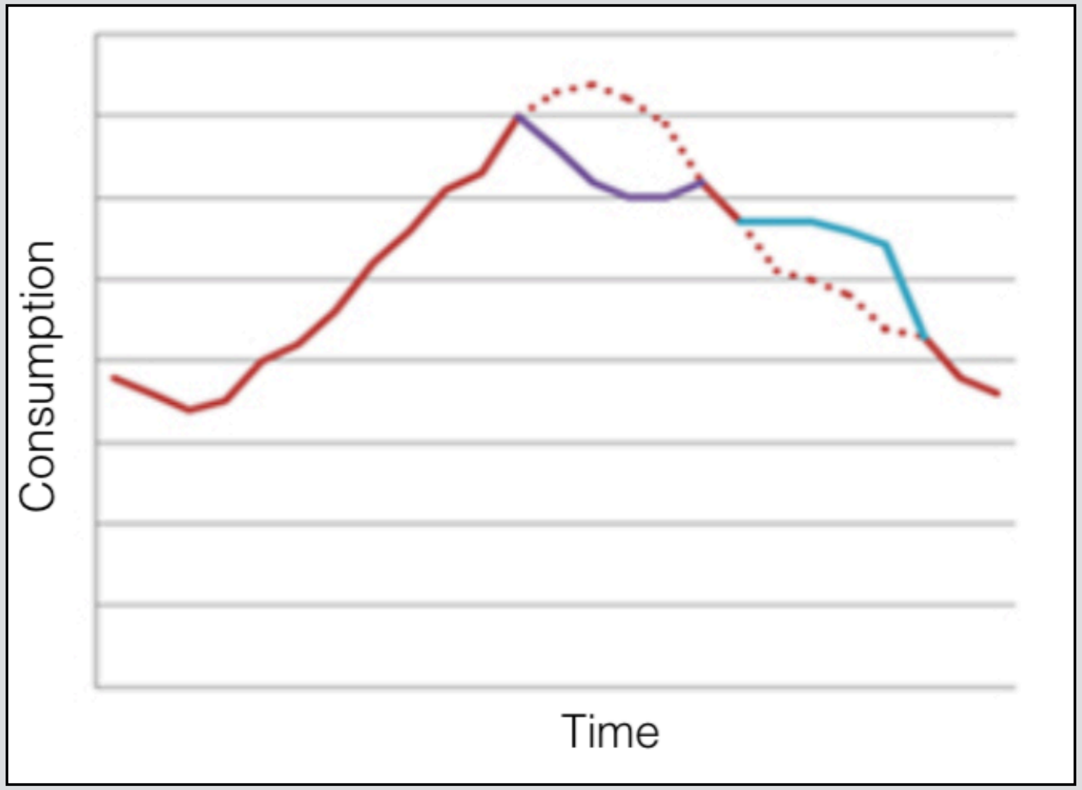
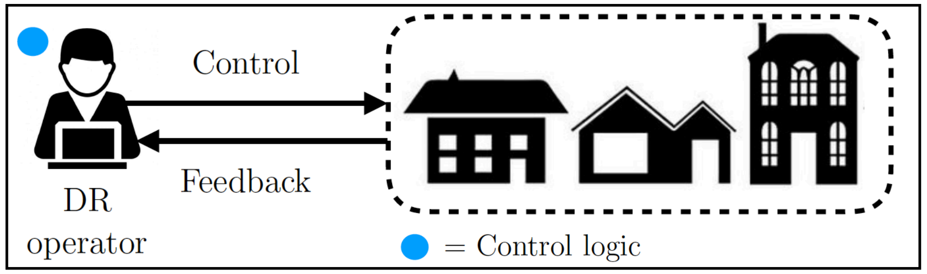
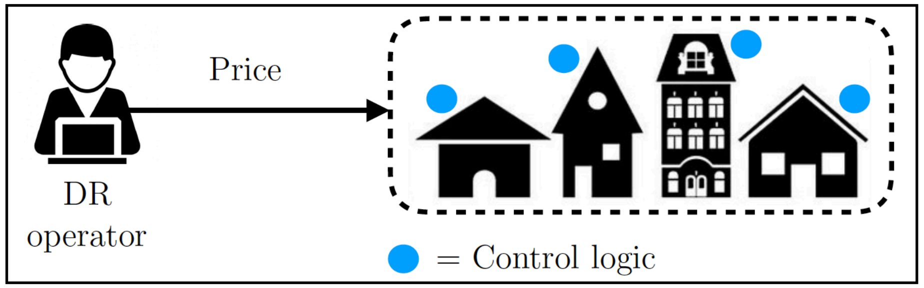


Explicit DR programs



- Minimised uncertainty
- Consumers' privacy

Implicit DR programs



- Consumers' autonomy
- Effective price signals

Unlocking consumers' flexibility potential

General framework for AS provision

Research question

Which **framework** can help to optimally exploit consumers' flexibility for AS provision at different voltage levels?

Unlocking consumers' flexibility potential

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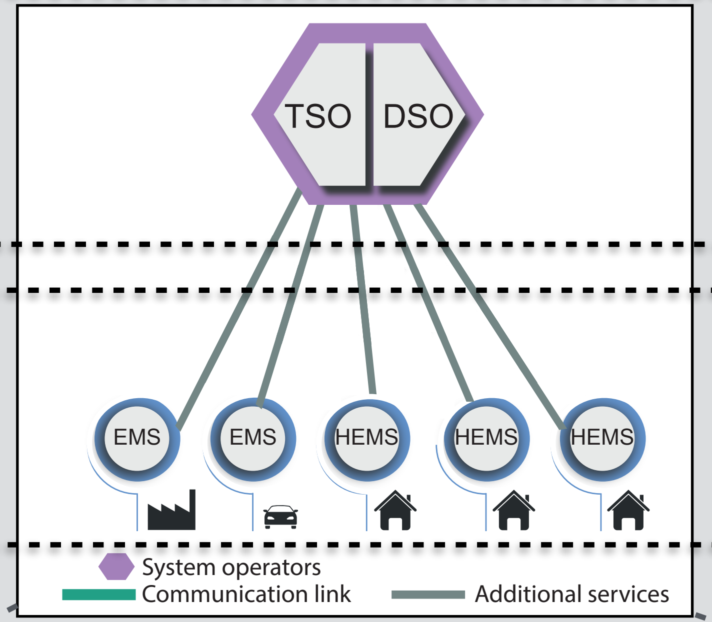
Ancillary Services 4.0 - core idea

Power system operators

Electricity consumers



1 **Time-varying prices**

2 **Adoption of controllers**

3 **One-way communication**

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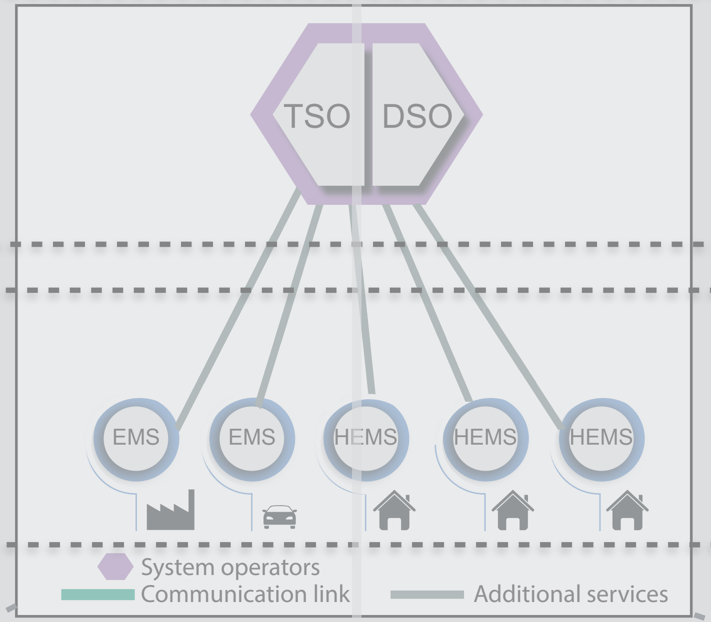

1 Time-varying prices

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Requirements

Dynamics

Non linearity

Stochasticity

Services at TSO /DSO

Fast

Cost effective

Consumers' autonomy / privacy

Scalable

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Which **framework** can help to optimally exploit consumers' flexibility for AS provision at different voltage levels?

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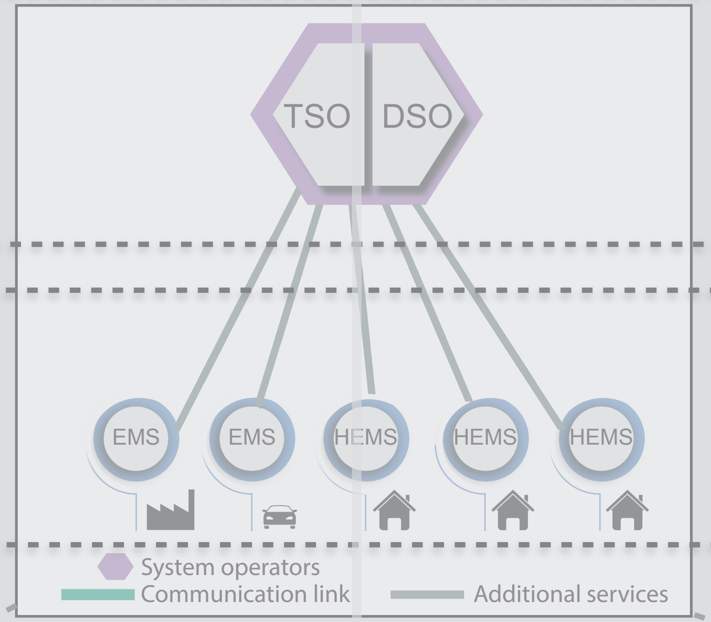

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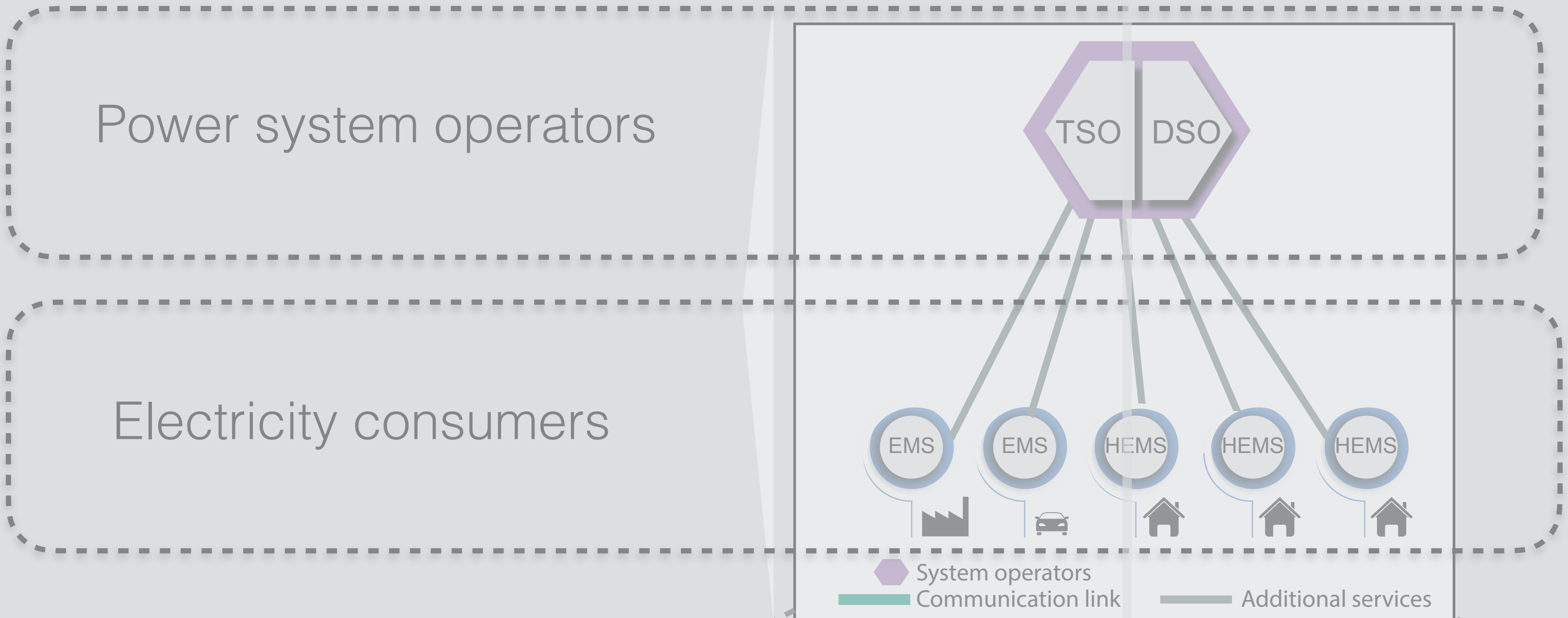

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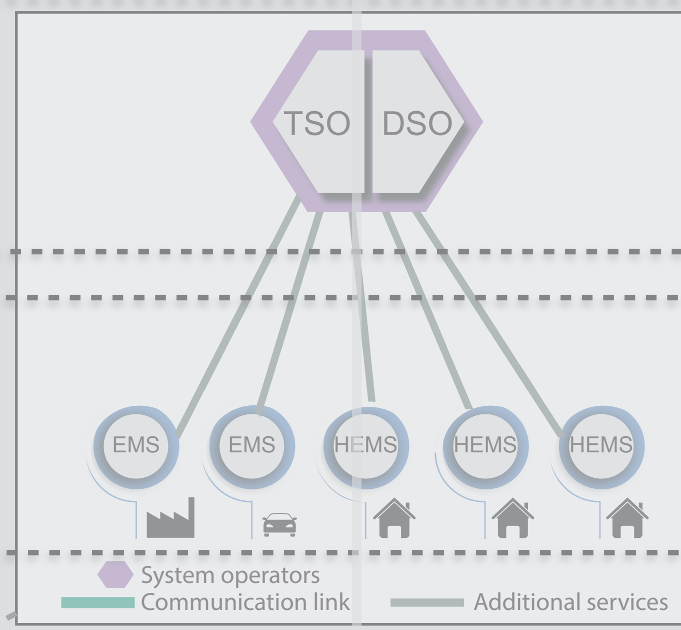

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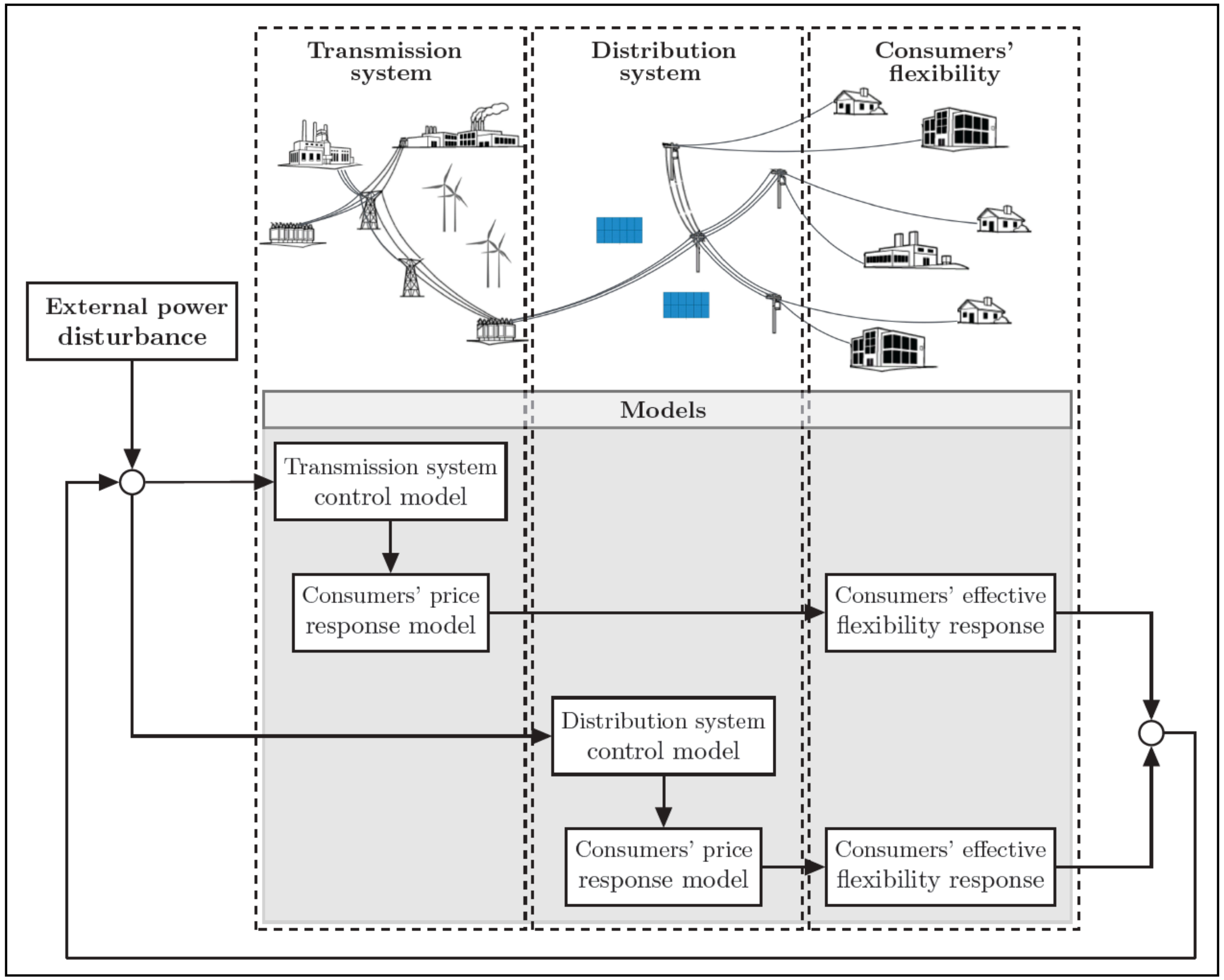
Unlocking consumers' flexibility potential

General framework for AS provision

Required models for AS4.0

Three types of models are needed to formulate AS4.0



Unlocking consumers' flexibility potential

General framework for AS provision

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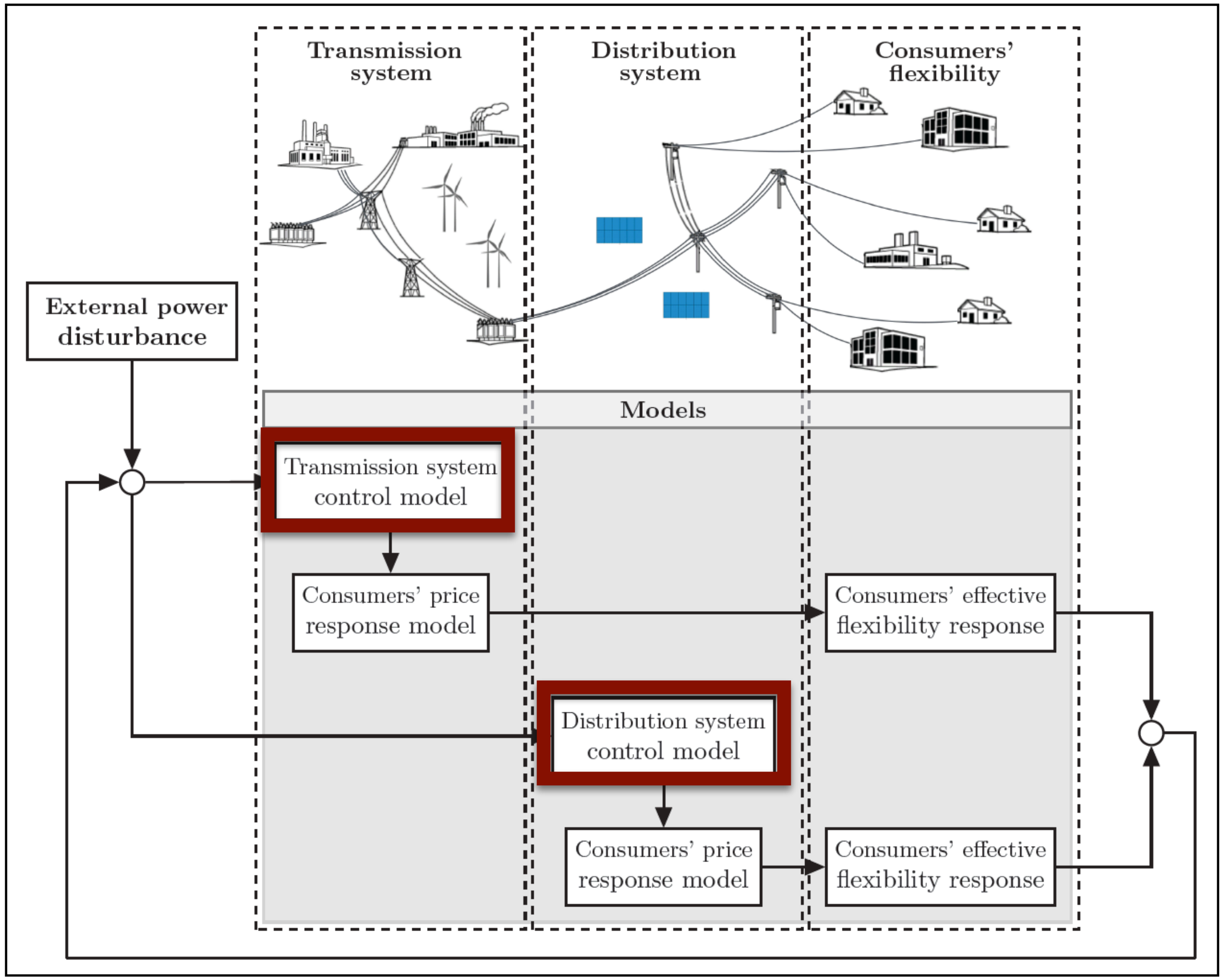

1 Power system control models

Effect on frequency/ voltage → Needed flexibility

Unlocking consumers' flexibility potential

General framework for AS provision

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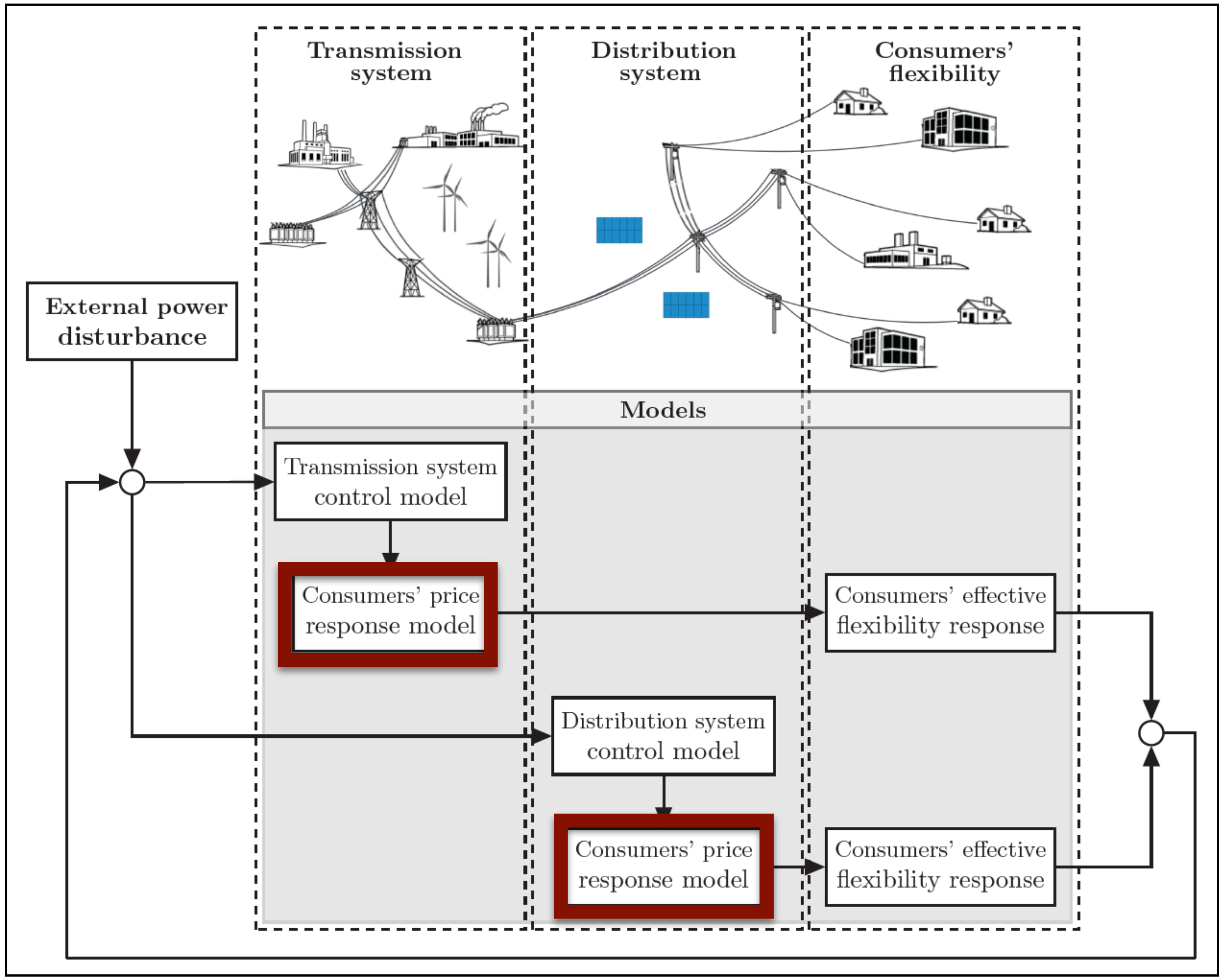

1. **Power system control models**

Effect on frequency/voltage → Needed flexibility

2. **Consumers' price response models**

Consumers' responsiveness toward prices → Proper price signals

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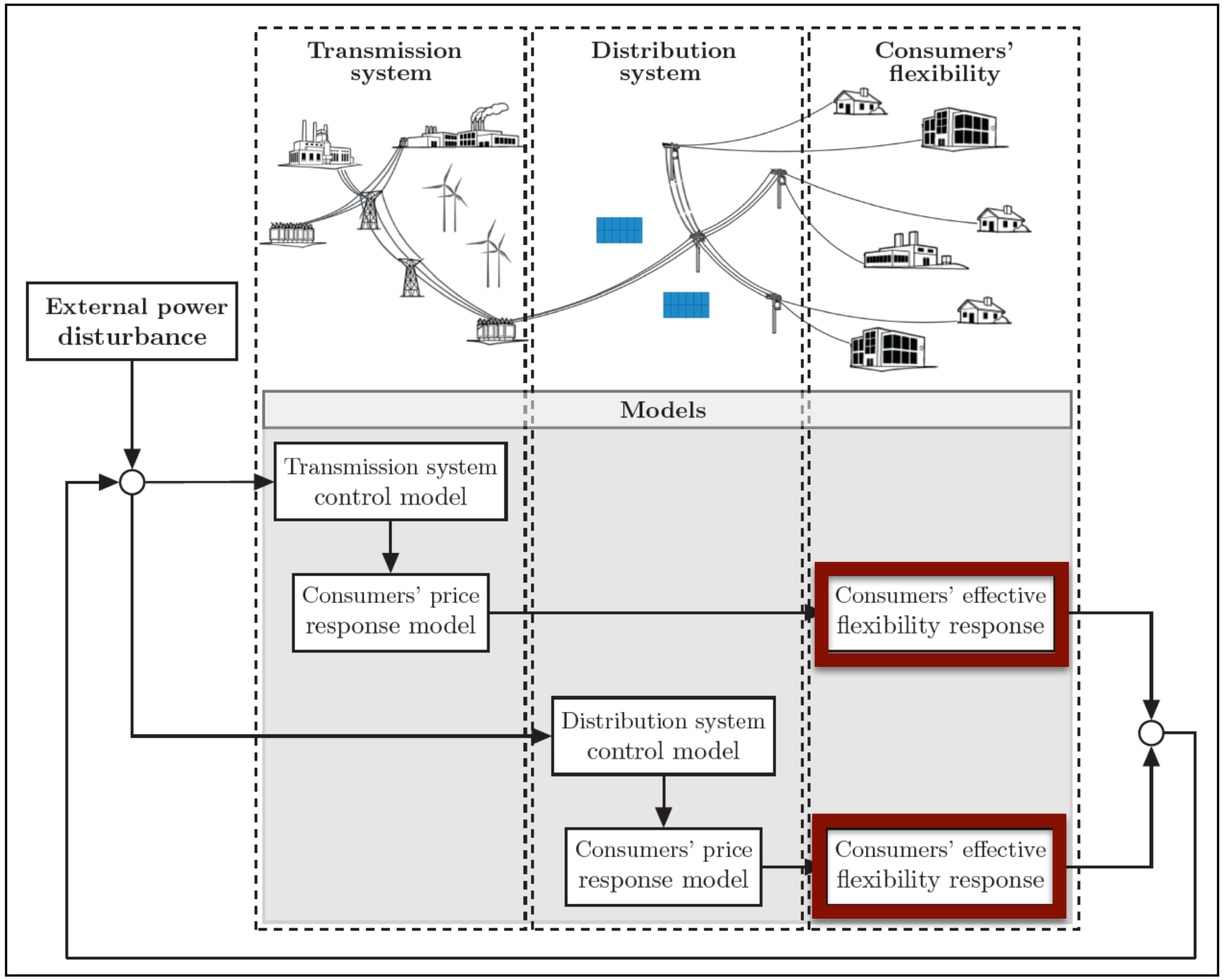


1. **Power system control models**

Effect on frequency/ voltage → Needed flexibility

2. **Consumers' price response models**

Consumers' responsiveness toward prices → Proper price signals

3. **Effective flexibility response models***

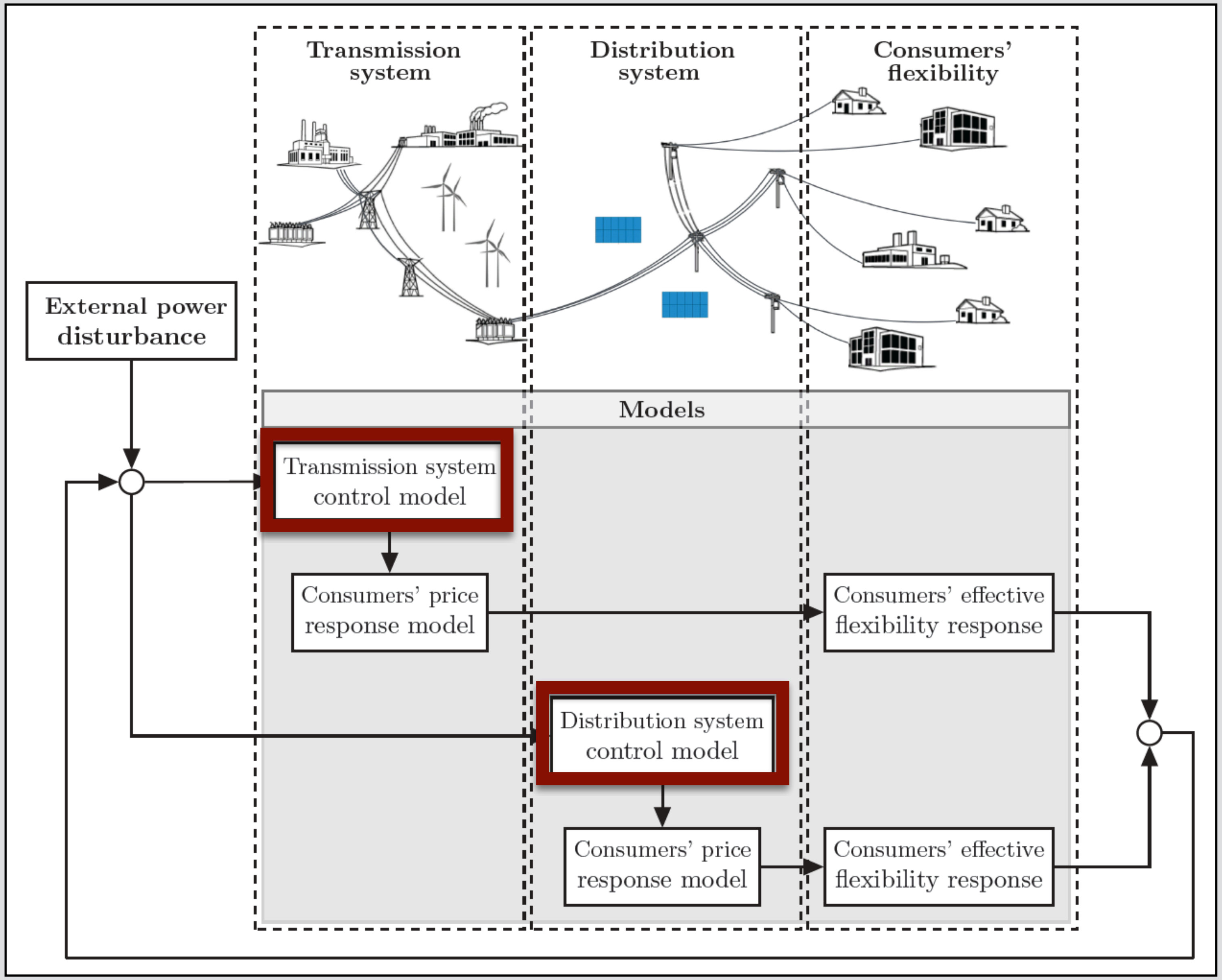
Actual consumers' behaviour → Achieved flexibility

Unlocking consumers' flexibility potential

General framework for AS provision

1

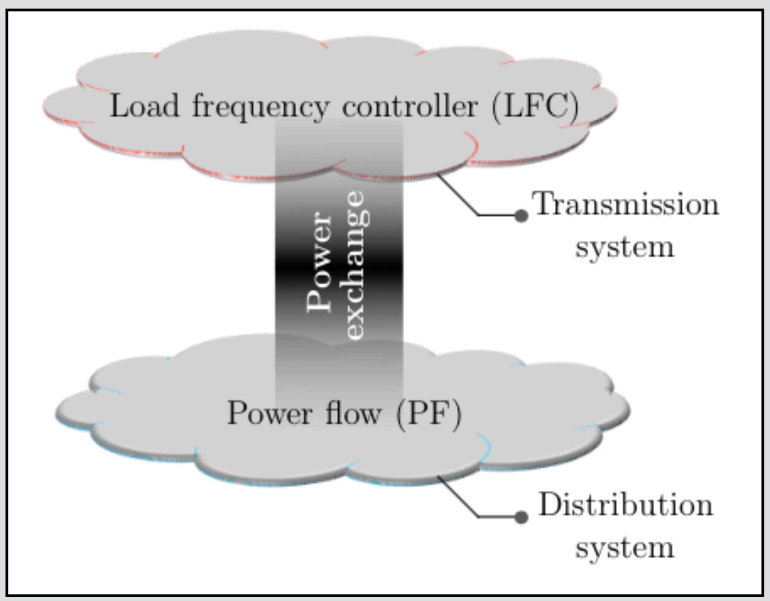
Power system control models



Unlocking consumers’ flexibility potential

General framework for AS provision

Power system control models



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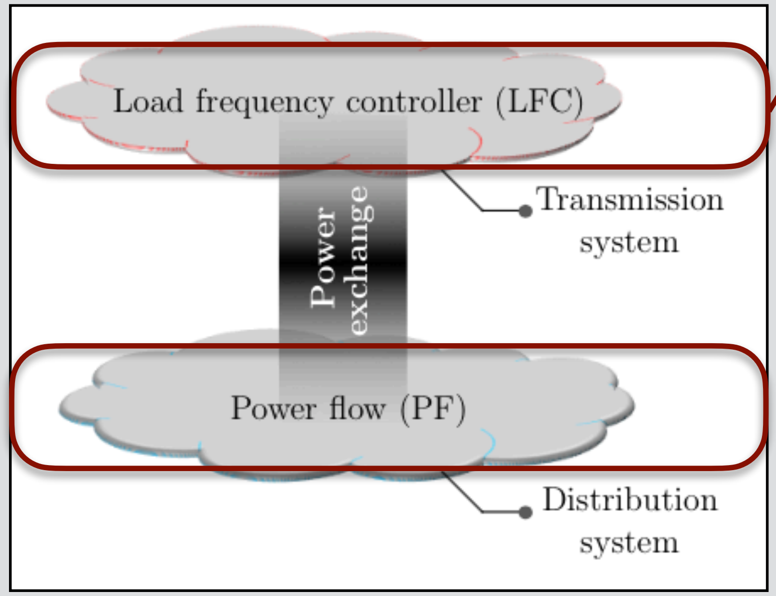
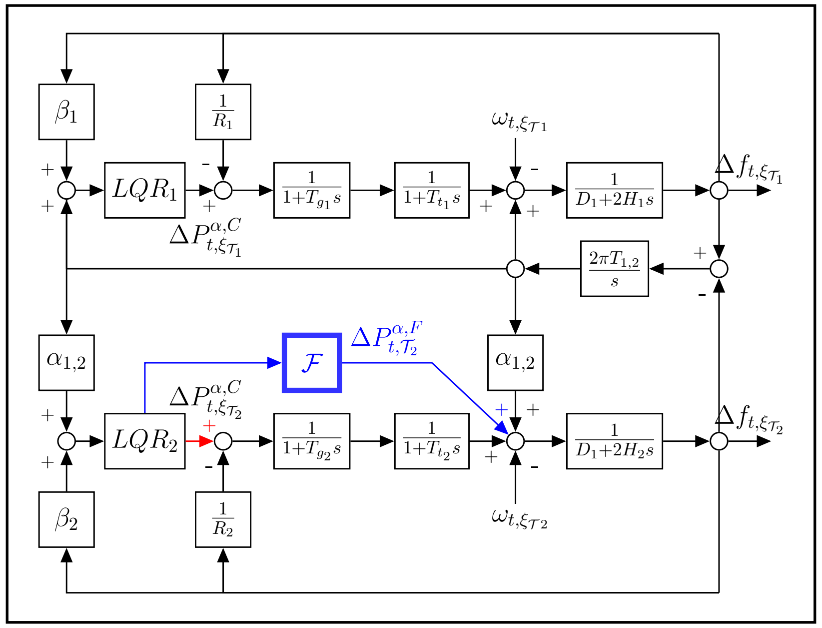


At the transmission level



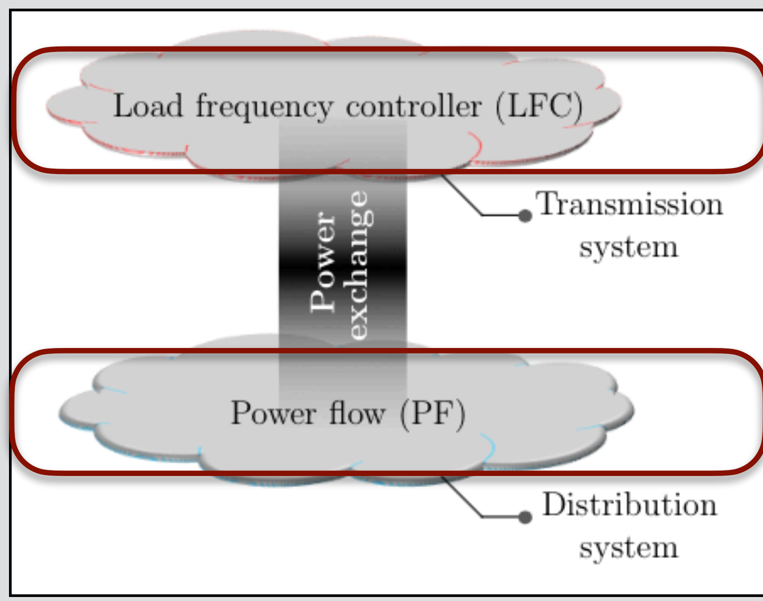
Two-area LFC

Comparison of performance between **conventional** generation units and **AS4.0**

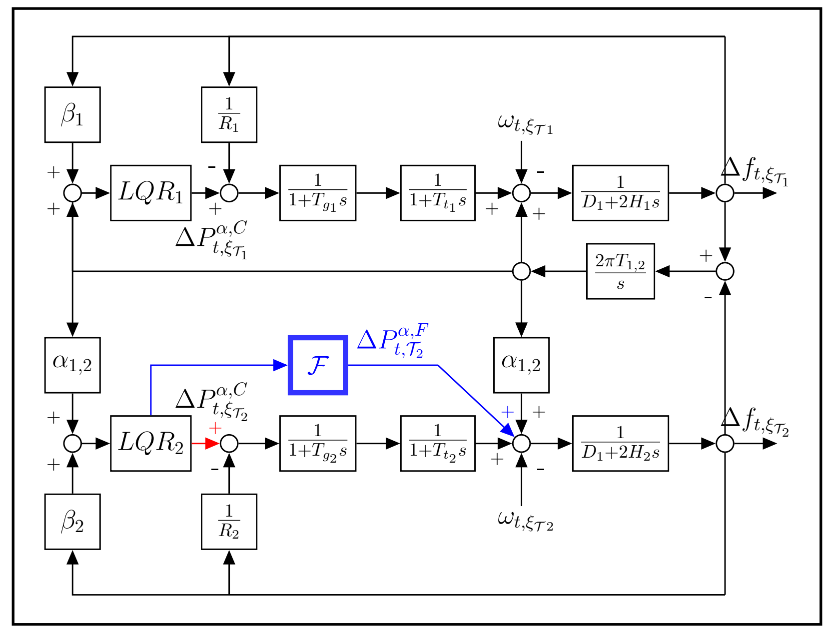
Unlocking consumers’ flexibility potential

General framework for AS provision

Power system control models



At the transmission level



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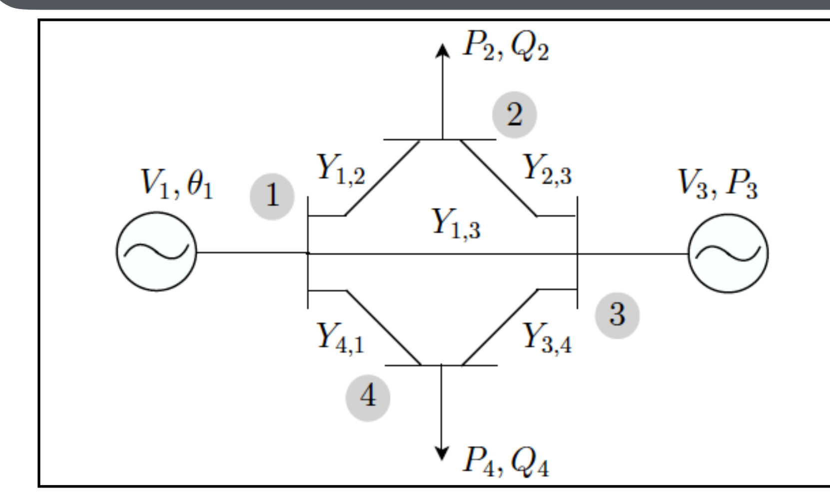
At the distribution level

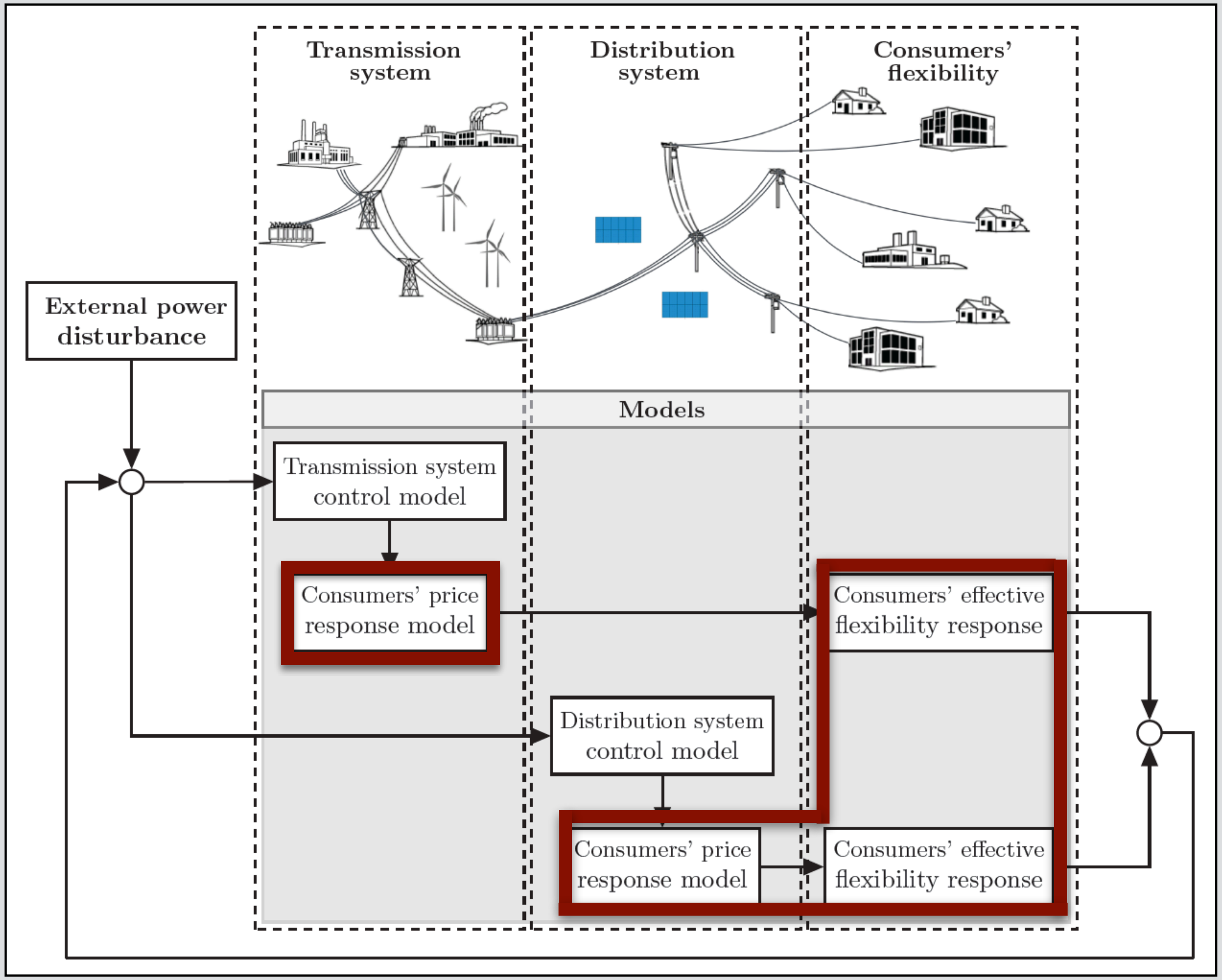


Unlocking consumers' flexibility potential

General framework for AS provision

2 3

Aggregate consumers' price response

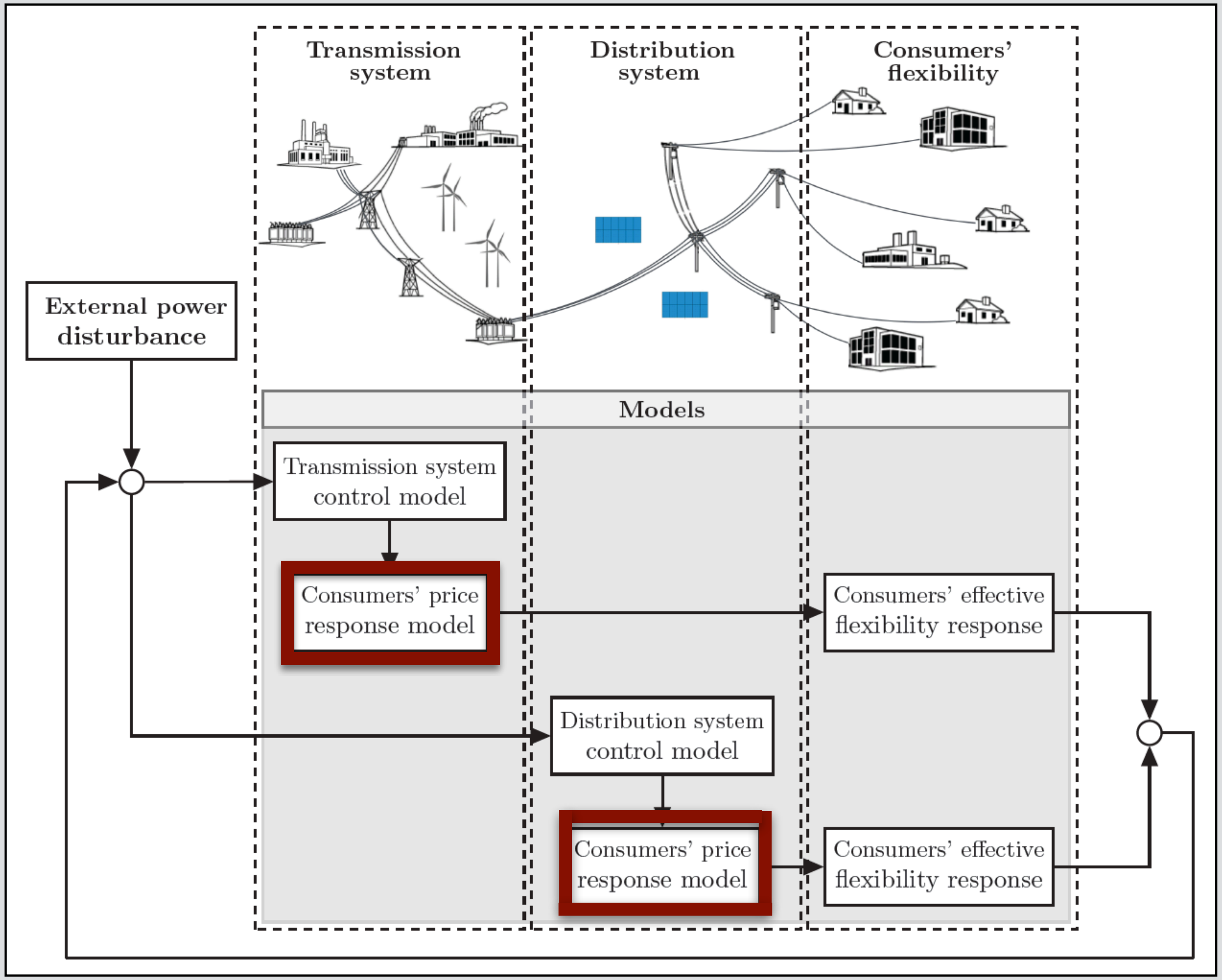


Unlocking consumers' flexibility potential

General framework for AS provision

Aggregate consumers' price response

Dynamic price formulation



Unlocking consumers' flexibility potential

General framework for AS provision

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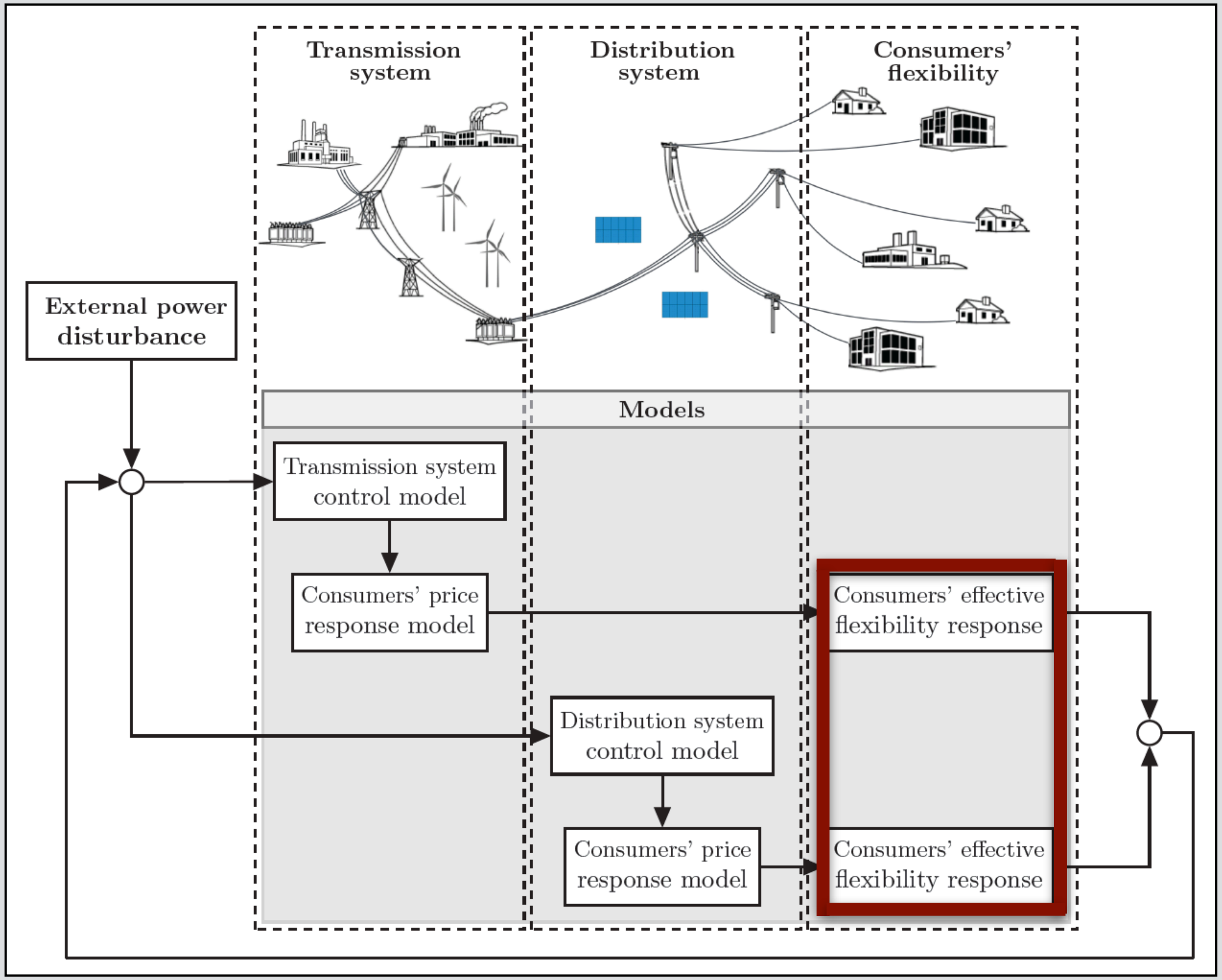
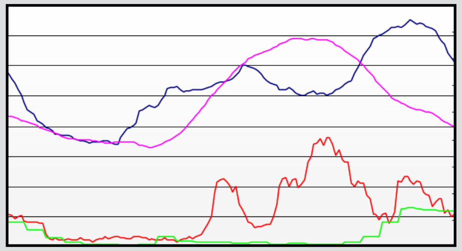


Realised consumers' response

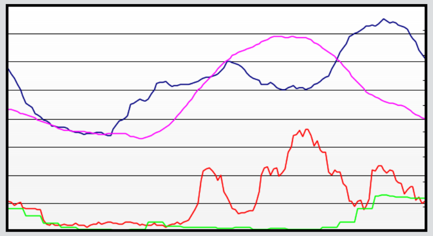


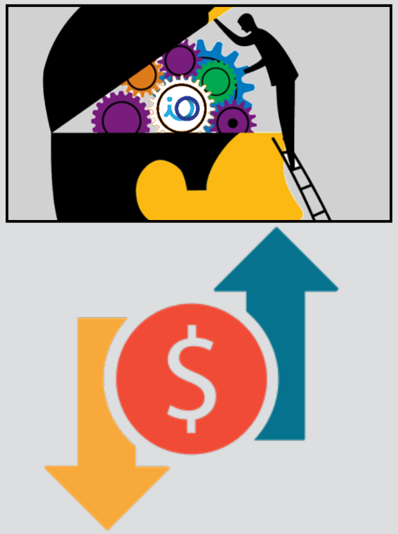
Unlocking consumers’ flexibility potential

General framework for AS provision

Aggregate consumers’ price response

Data can be used to model consumers’ reaction toward prices.





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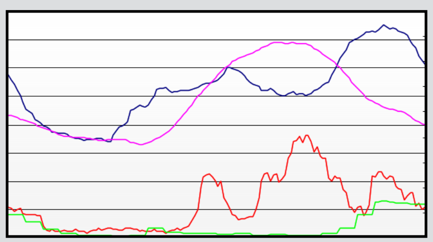
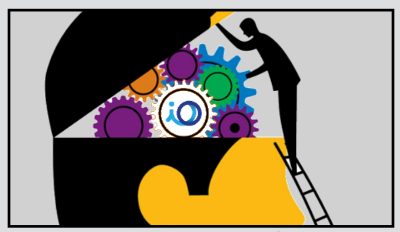
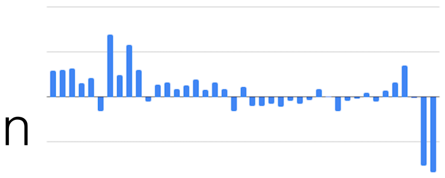




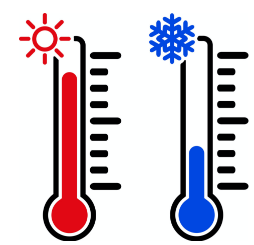
Electricity consumption



Time-varying electricity price

Time

Temperature



Type of consumer

...

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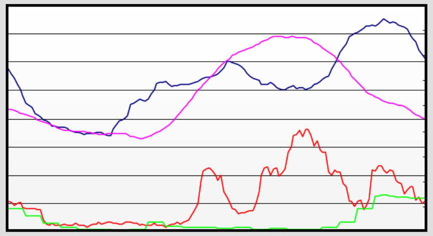

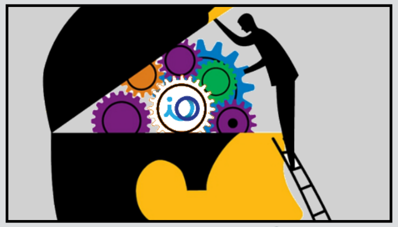

Due to **data scarcity**, models are adopted.

Different models at transmission and distribution levels:

- Size
- Consumers’ composition

Unlocking consumers' flexibility potential
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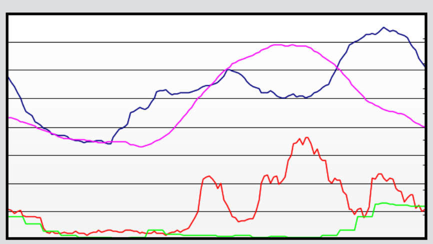

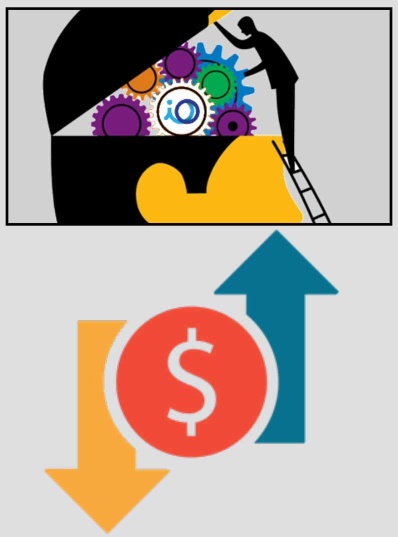

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At the transmission level

Frequency is **not** a **local** issue → Aggregate consumers' flexibility

Model	
Model	→ Cost minimisation
Montecarlo simulation	→ Aggregate flexibility
Neural network	→ Time varying prices

Unlocking consumers' flexibility potential

General framework for AS provision

Aggregate consumers' price response

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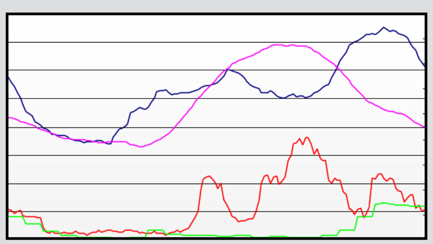

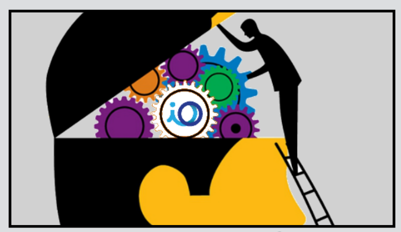

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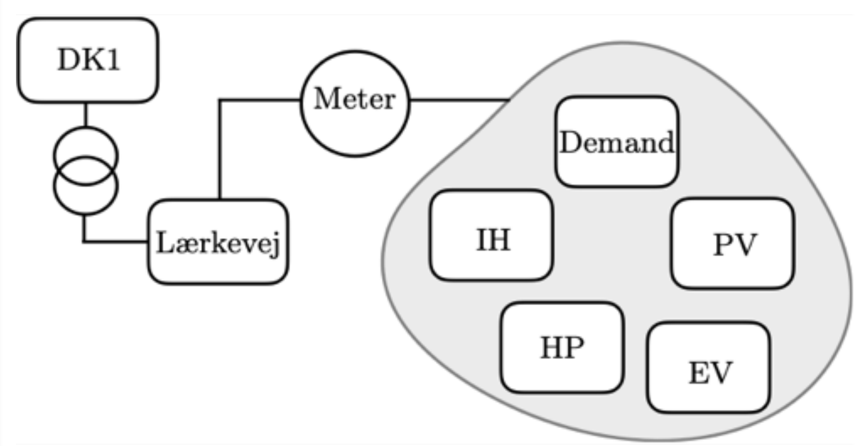

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General framework for AS provision

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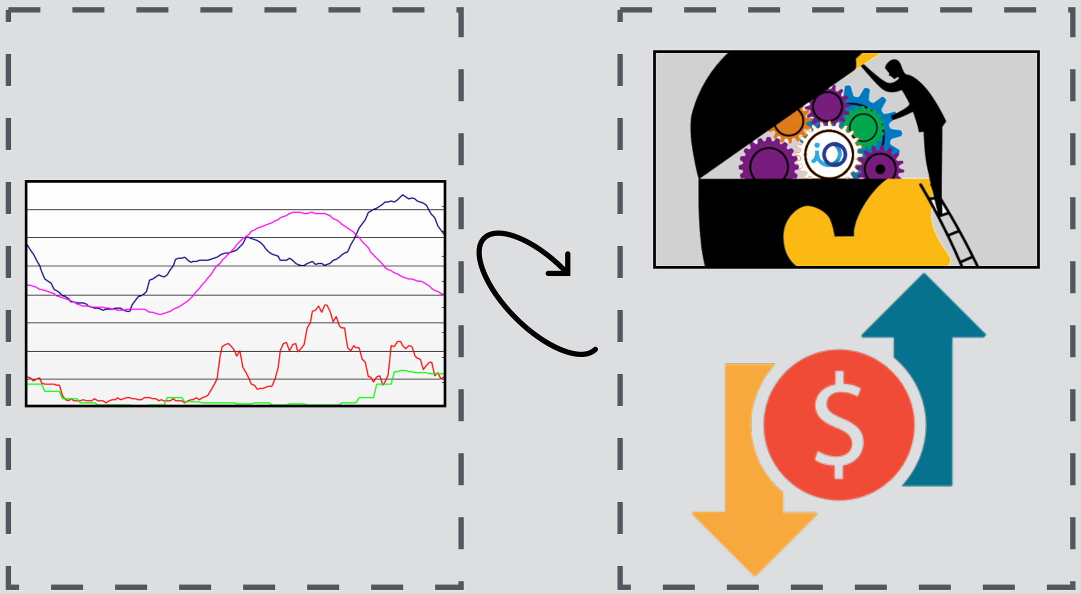

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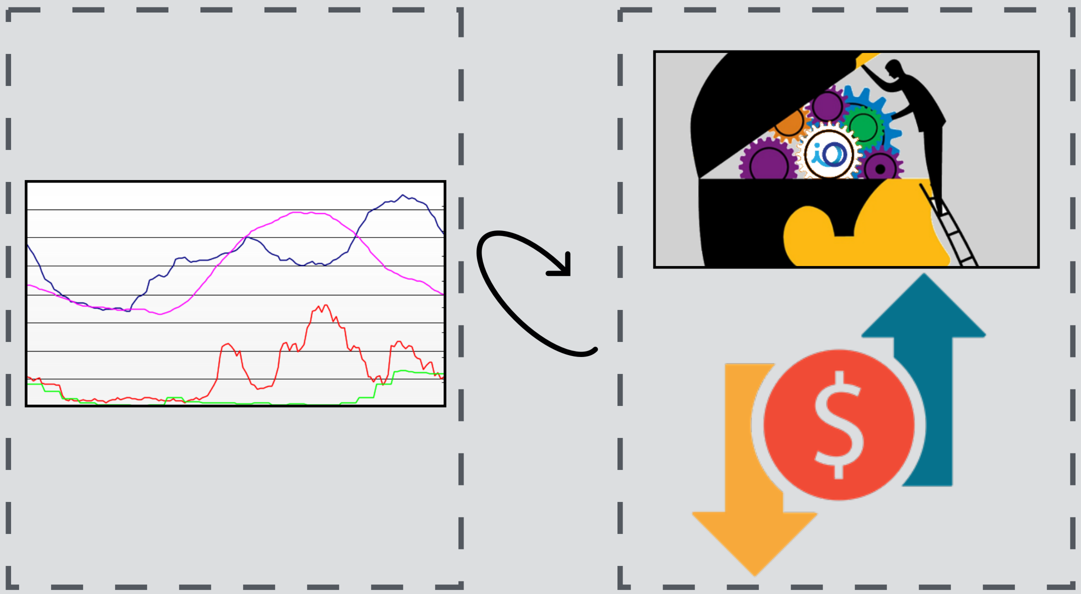

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→ Cost minimisation

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At the distribution level

Voltage is a **local** issue → Flexibility at each DSO bus; DSO buses clustering

Model

PI controller

→ Consumers’ willingness

→ Voltage deviation

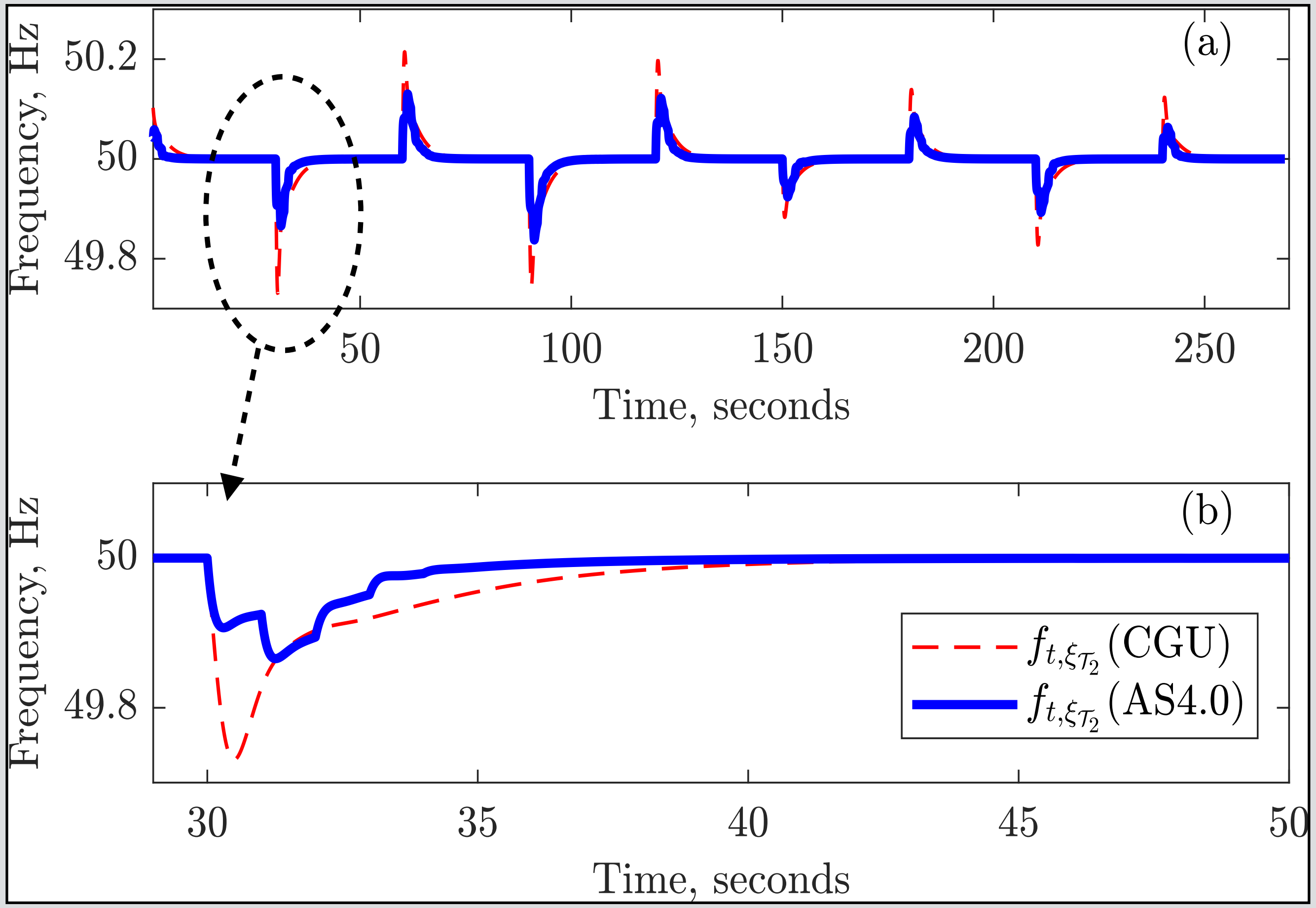
Unlocking consumers' flexibility potential

General framework for AS provision

Simulation results

Frequency at the transmission level

AS4.0 **reduces** the **frequency deviation** by around **50%** compared to the conventional method.



Time and disturbance injected, (sec, MW)	Maximum frequency deviation, Hz		Deviation reduction, %
	CGUs-based AS	AS4.0	
[1,1000]	0.10	0.06	40 %
[30,350]	-0.27	-0.13	52 %
[60, 852]	0.21	0.13	38 %
[90, 500]	-0.26	-0.16	38 %
[120, 1148]	0.20	0.12	40 %
[150, 1000]	-0.12	-0.08	33 %
[180, 1300]	0.14	0.08	42 %
[210, 1056]	-0.17	-0.11	35 %
[240, 1500]	0.12	0.07	41 %

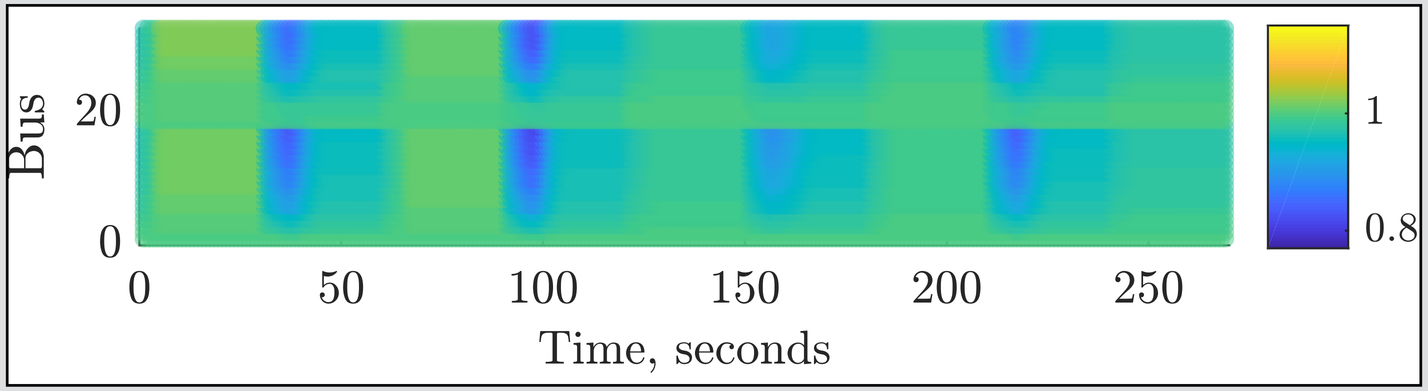
Unlocking consumers' flexibility potential

General framework for AS provision

Simulation results

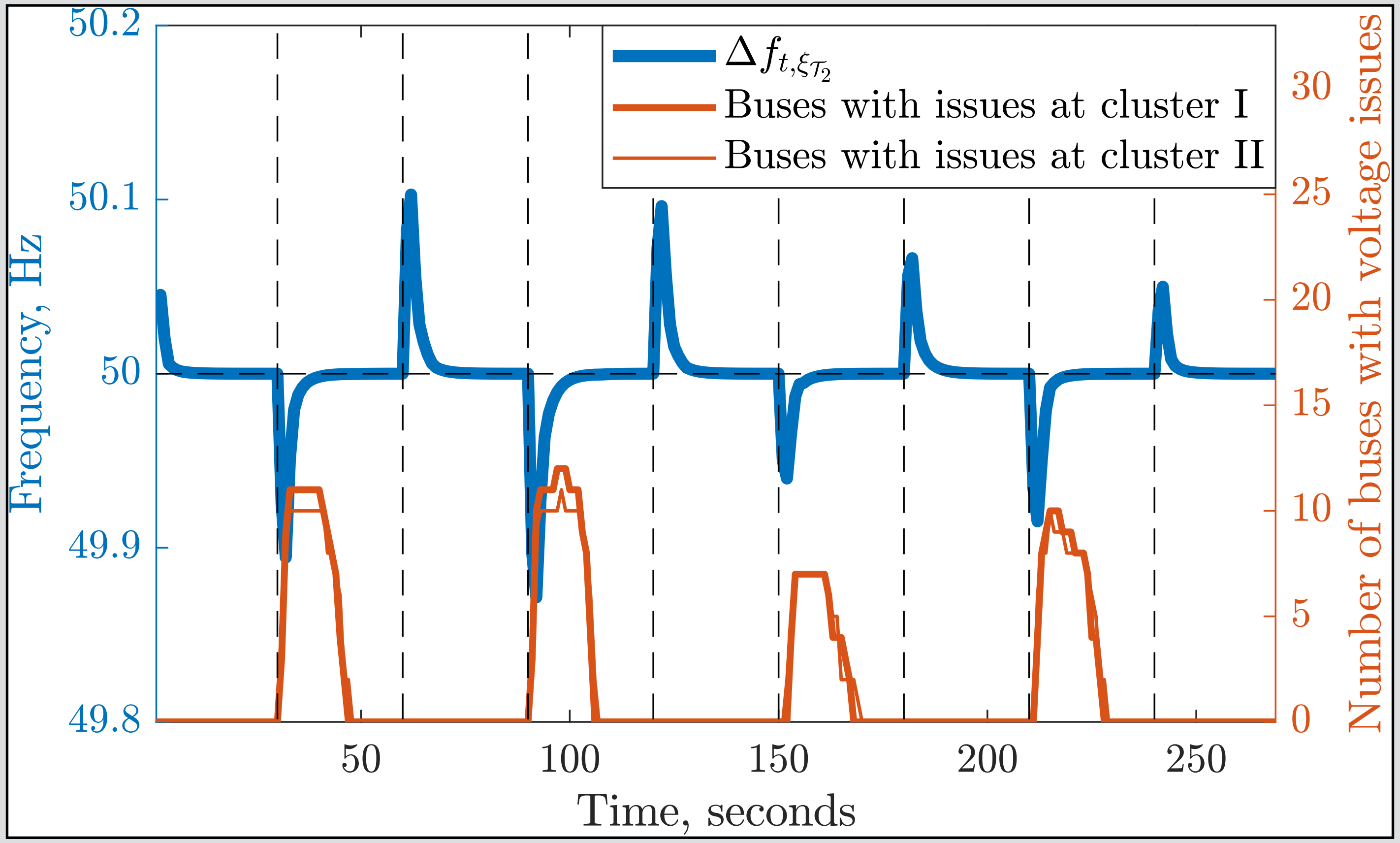
Voltage at the distribution level

AS4.0 manages to **mitigate** the **voltage** issues at the DSO buses.



Operational issues at TSO and DSO

The **number of buses** with voltage issues **decreases** over time.



Concluding remarks
Conclusions

Conclusions

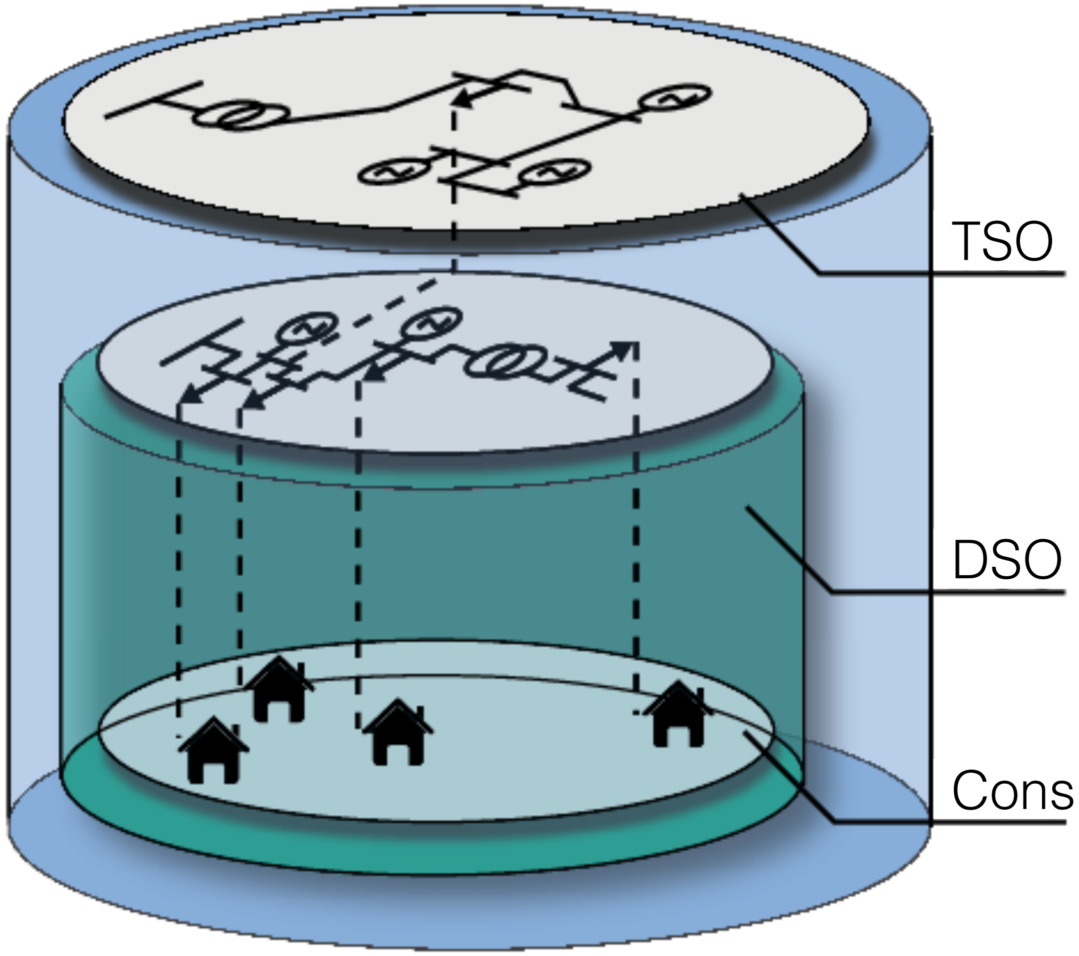
Electricity **consumers** have high potential to provide flexibility to the grid.

AS4.0 is a new approach for AS provision which is based on:

- time varying electricity prices
- one-way communication
- control techniques

It successfully handled the operational issues at **TSO and DSO** level.

AS4.0 achieved better performance than the **conventional** generation units-based method.



Thank you!

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