

A Control-Based Approach for Solving Ancillary Service Problems in Smart Grids

Mathematical Optimization in the Decision Support Systems for Efficient and Robust Energy Networks, Modena, IT

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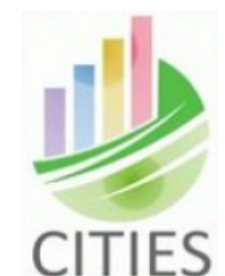


mathematics × models ×
computations = more energy

A COST PROJECT

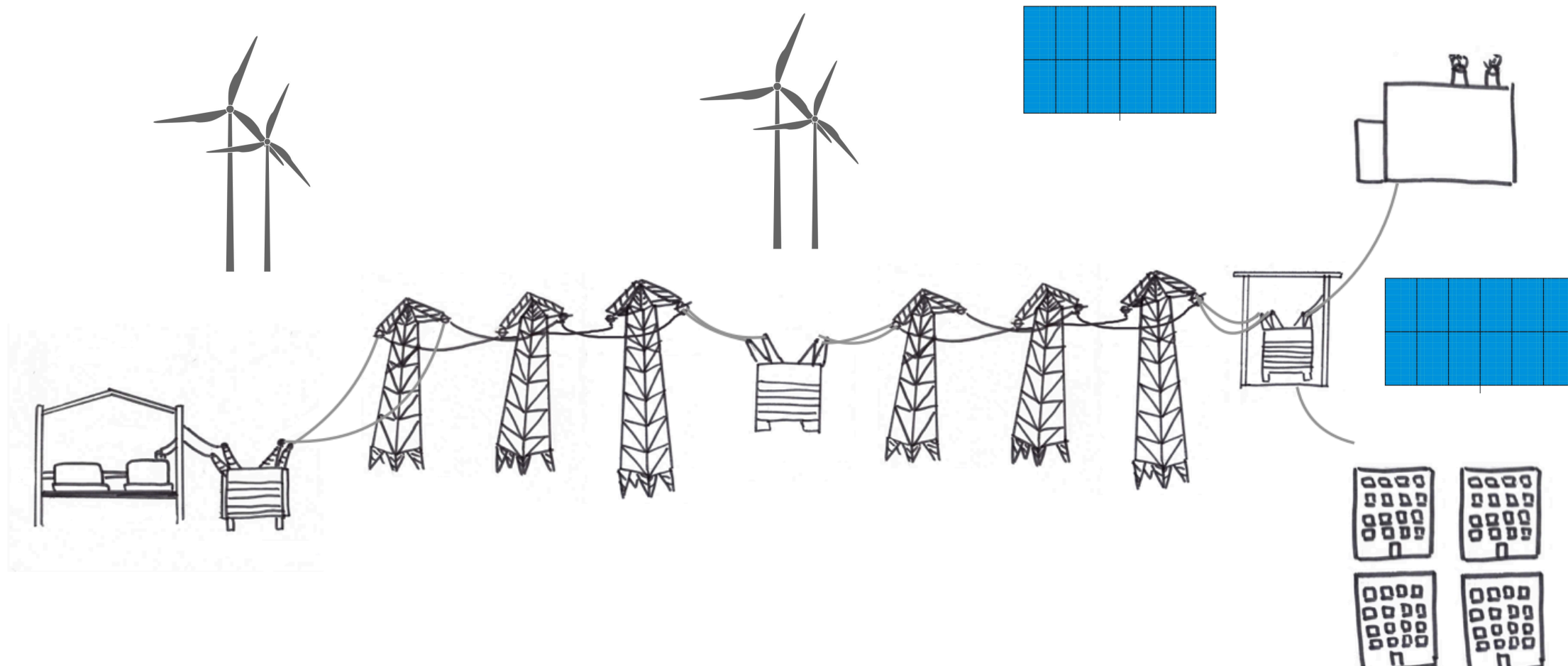


COST is supported by the EU RTD Framework Programme



The electricity supply service

Penetration of RES

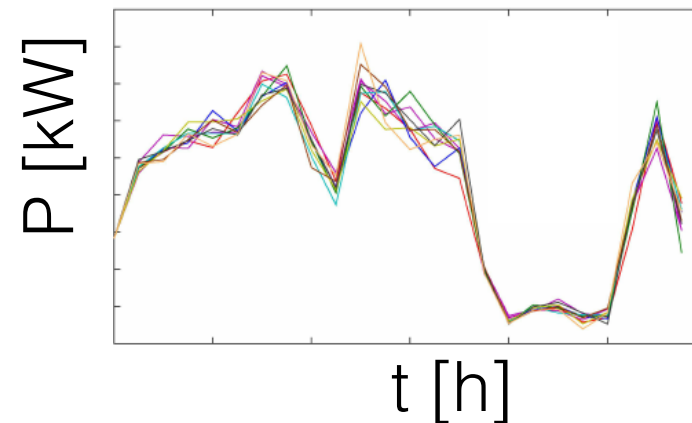


The electricity supply service

Challenges introduced by RES

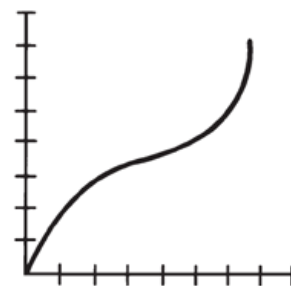
Adding the RES to the generation portfolio affects the quality of service and power system operation because of:

Stochasticity



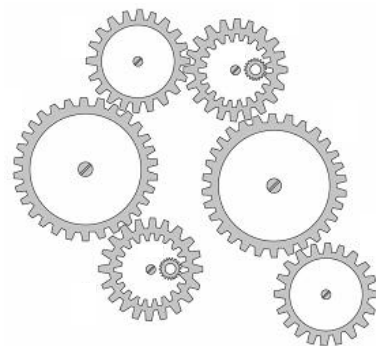
The generation from RES **cannot be planned** in the same way as conventional power plants.

Non-linearity



The generation can follow a **non-linear trend**.

Dynamics



Different dynamics can occur in **space and time**.



The electricity supply service

Consequences for the AS

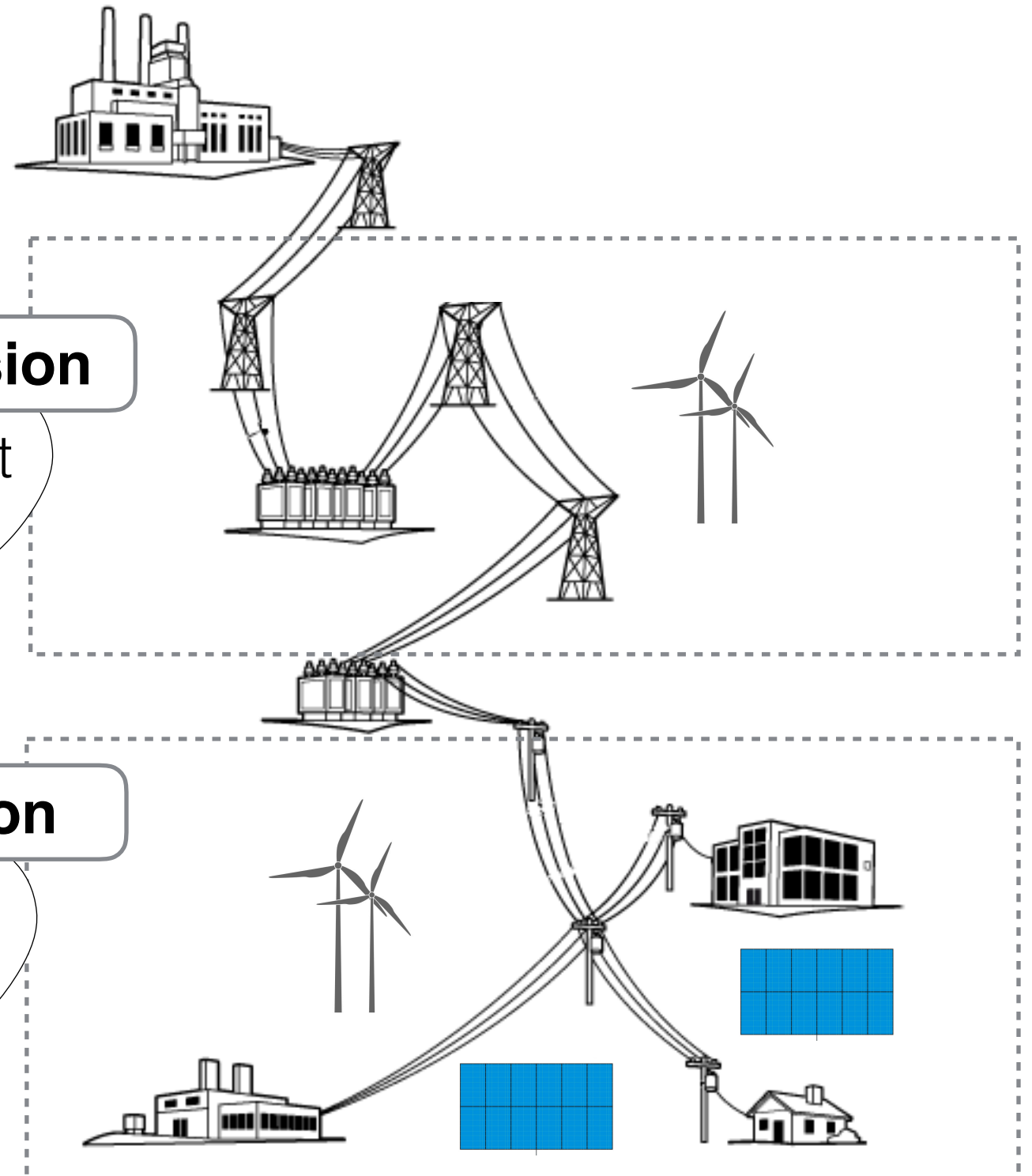
This is particularly affecting the provision of the ancillary services:

Transmission

Congestion management
Frequency control

Distribution

Congestion management
Voltage control
Balancing



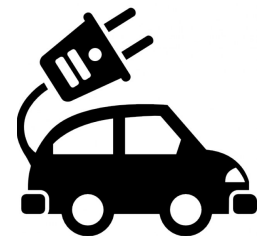
The electricity supply service

Exploiting the energy flexibility

Flexible resources



Flexible loads, storage and generation can **adapt** their **behaviour** according to the **necessity** of the grid.



They need to be **coordinated** in a **fast** and **efficient** manner in order to be valuable.

Integrated energy systems

Integrating the energy system might provide **extra flexibility**.

Today it is still **missing** the **policies** and **operational schemes** to allow such implementation.



Outline

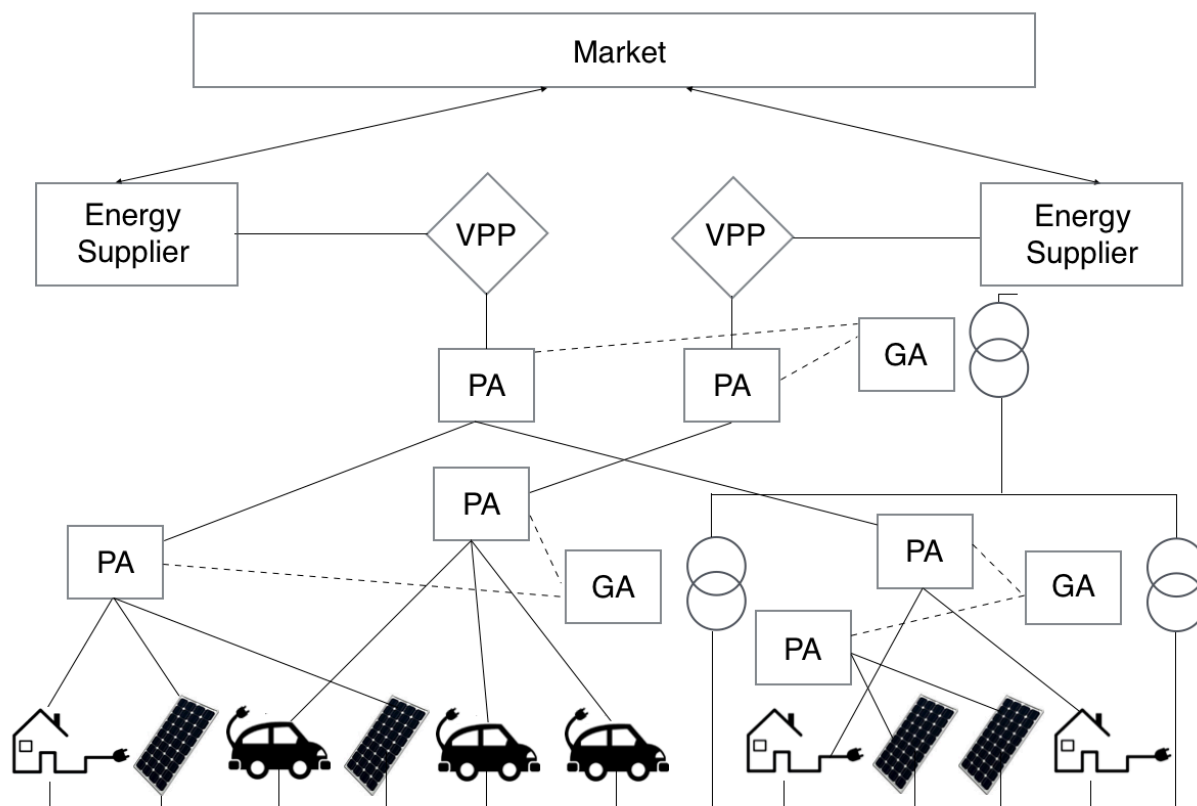
- Coordinating flexible resources
- Proposed methodology
- Main advantages of the proposed methodology
- Main concerns to be addressed
- Conclusions

Coordinating flexible resources

Different approaches

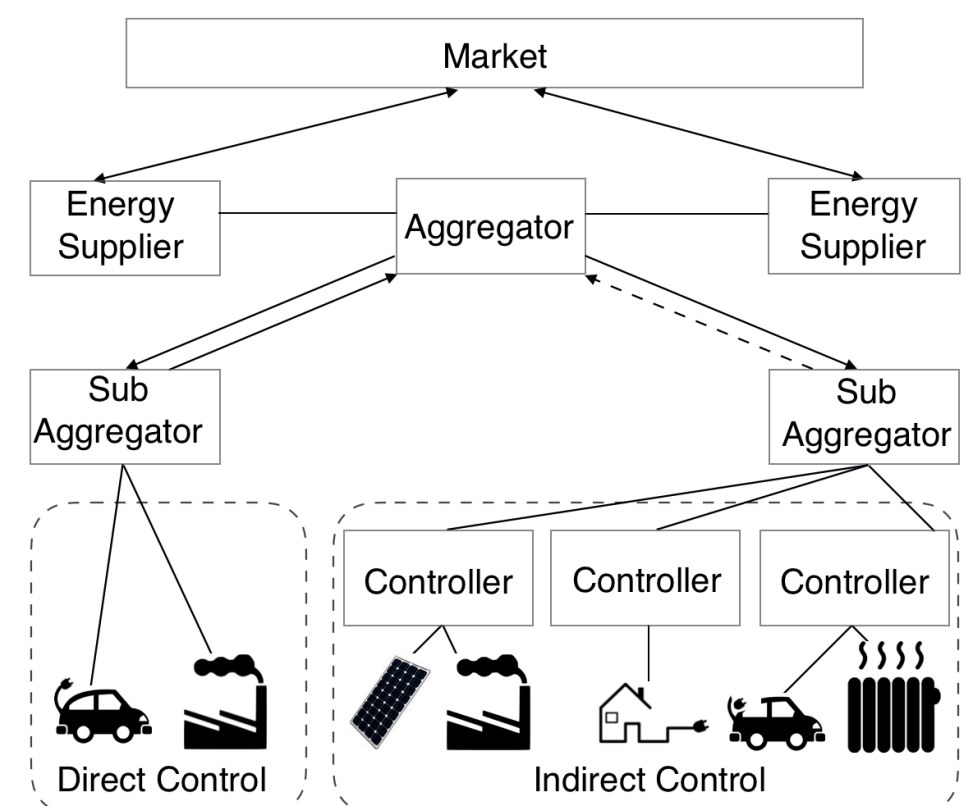
Different possibilities can be investigated for the coordination of the flexible resources:

Market- based approach



Market operation is intended all the way down to the prosumers' level.

Control- based approach



Control problem is formulated at the prosumers' level.

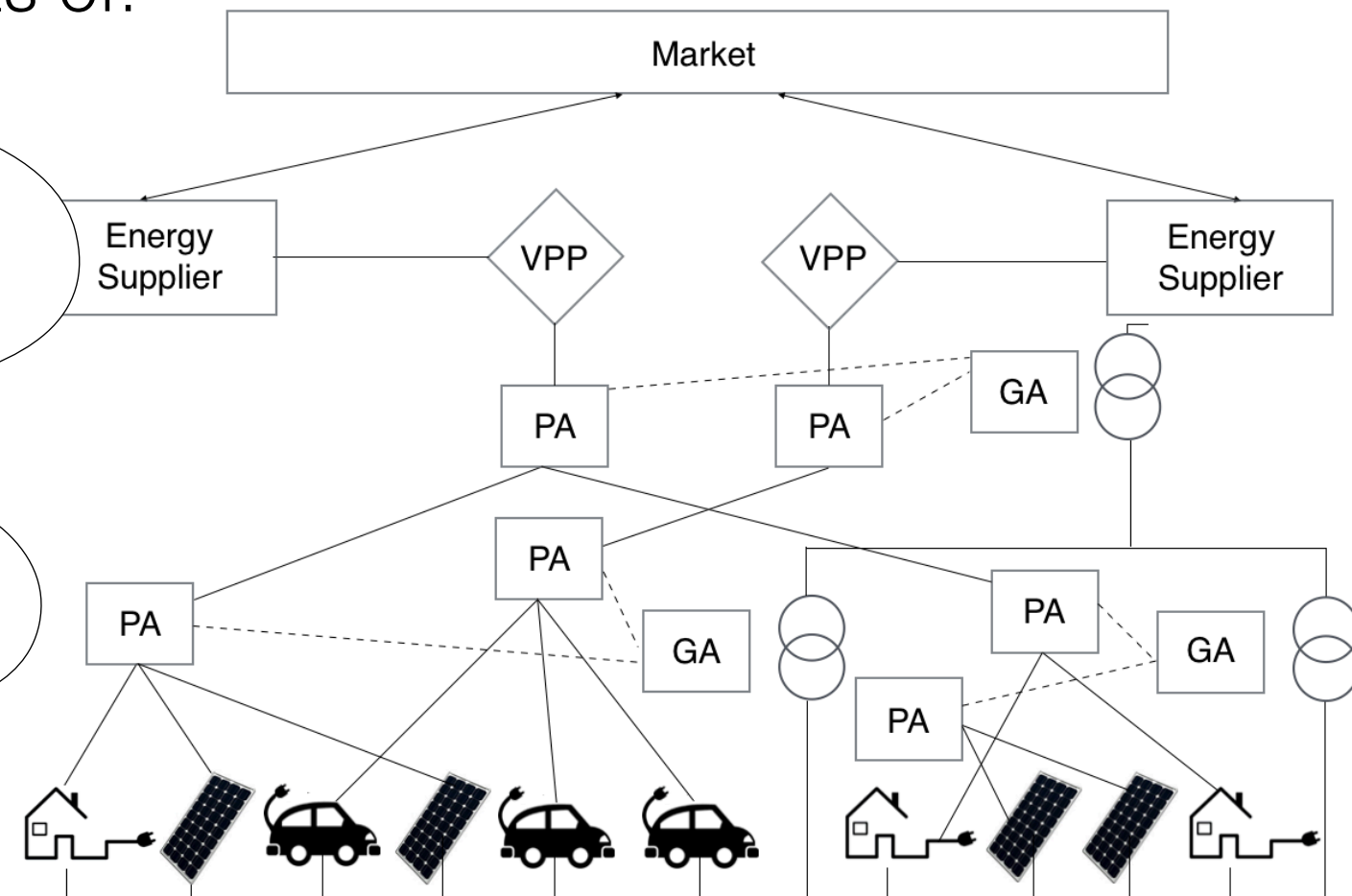
Coordinating flexible resources

Market-based approach

The market-based approach consists of:

I. Aggregating DERs through the support of an agent.

II. Formulating bids to submit to the market.

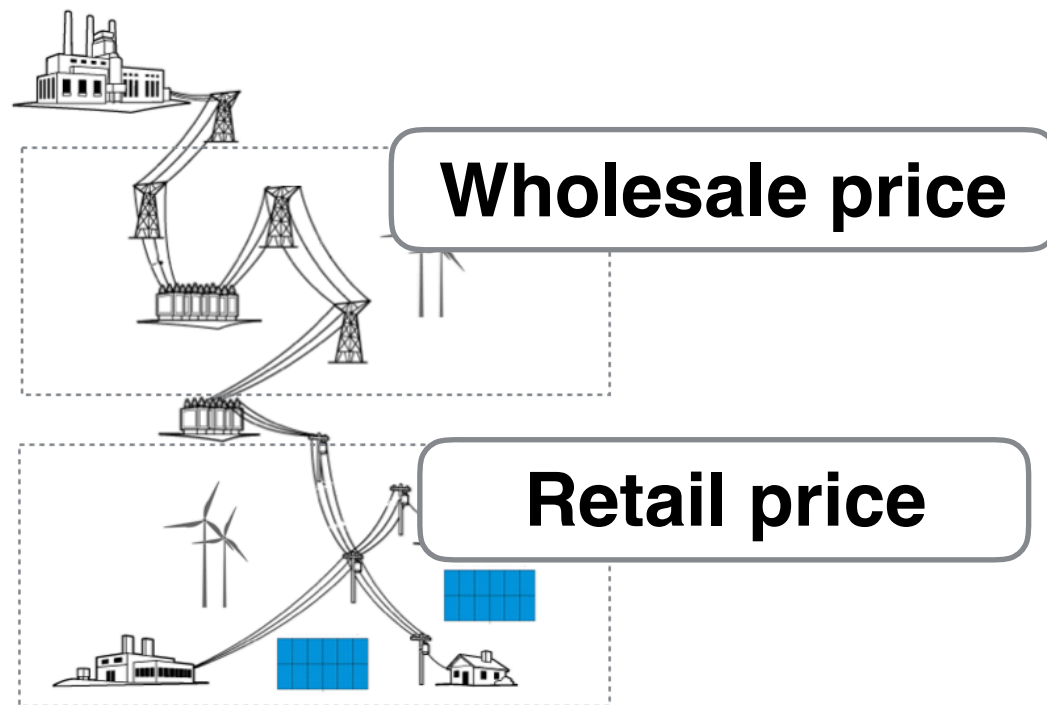


However, such approach raises several concerns due to the fact that the AS market provisioned in this approach is:

Static
Linear **Deterministic**

Coordinating flexible resources

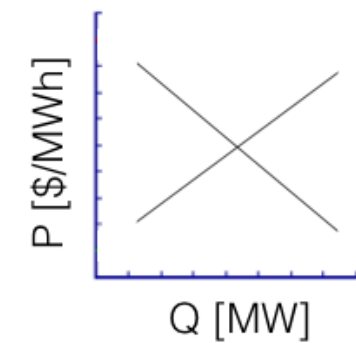
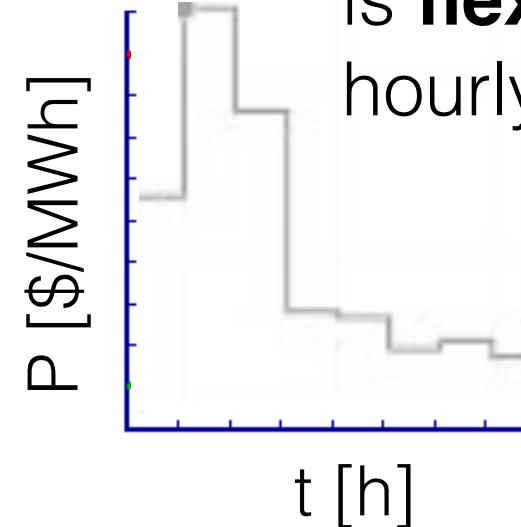
The electricity price



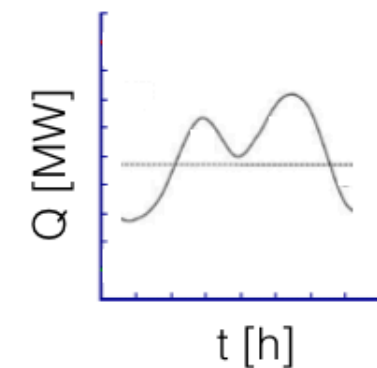
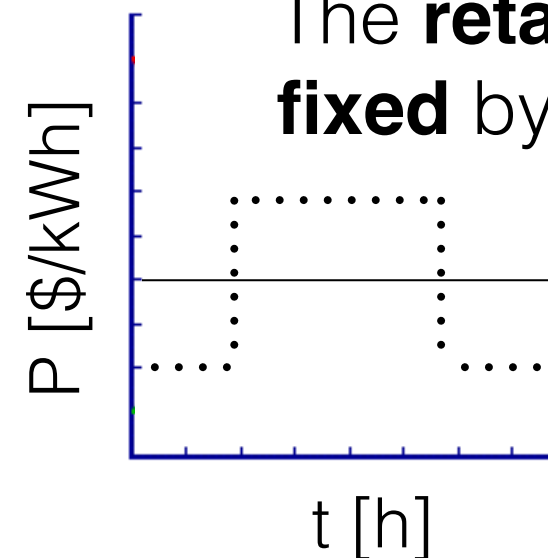
For the retail price there is no flexibility and the **prosumers do not consider the condition of the grid in their actions.**

It is fundamental to **reconsider the formulation** of the **retail electricity price** to exploit the **price responsiveness** of the **flexible** energy resources.

The **wholesale** electricity price is **flexible** and **changes** sub-hourly.



The **retail** electricity price is **fixed** by the **utility**.



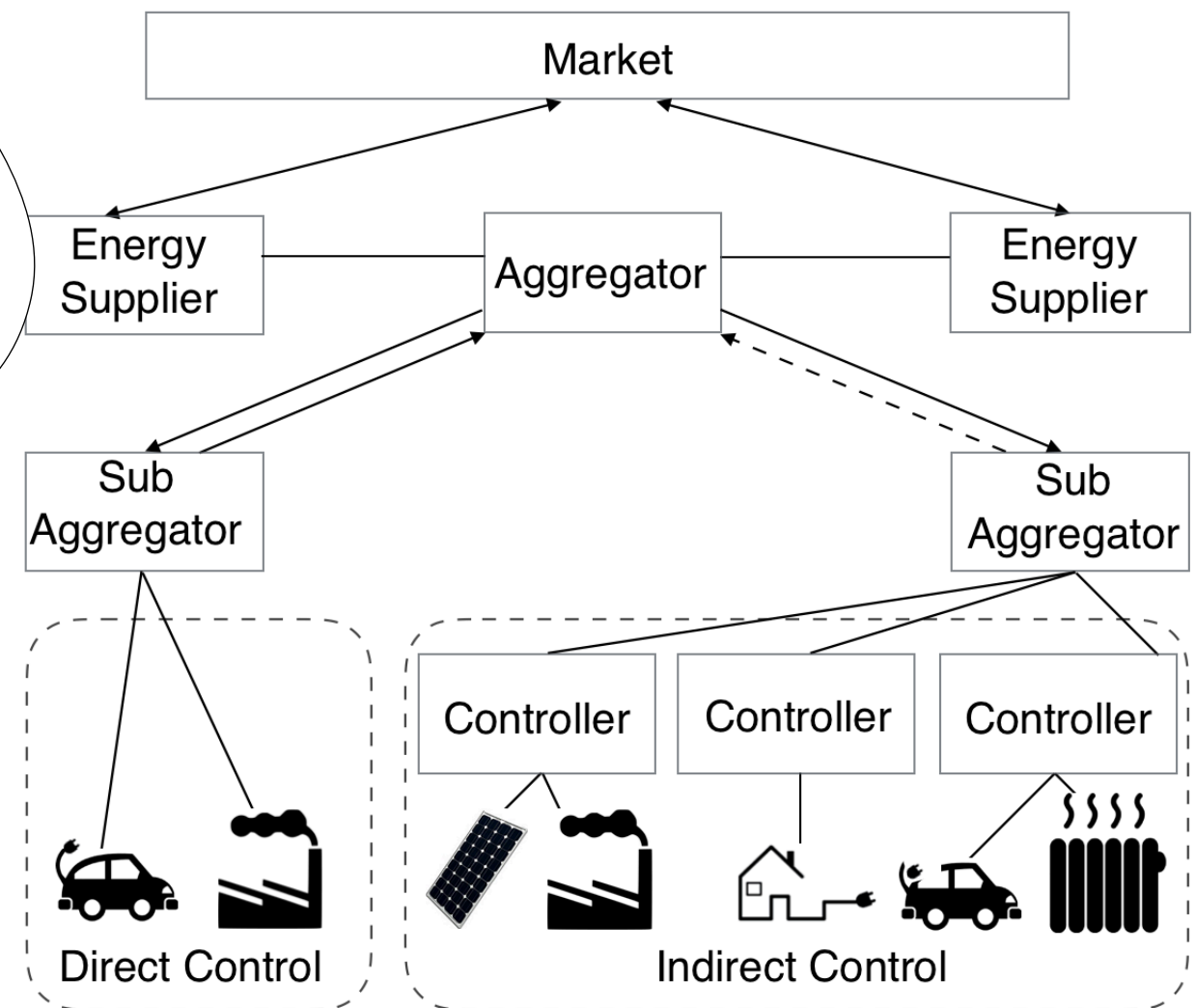
Coordinating flexible resources

Control-based approach

The control-based approach is formulated in two steps:

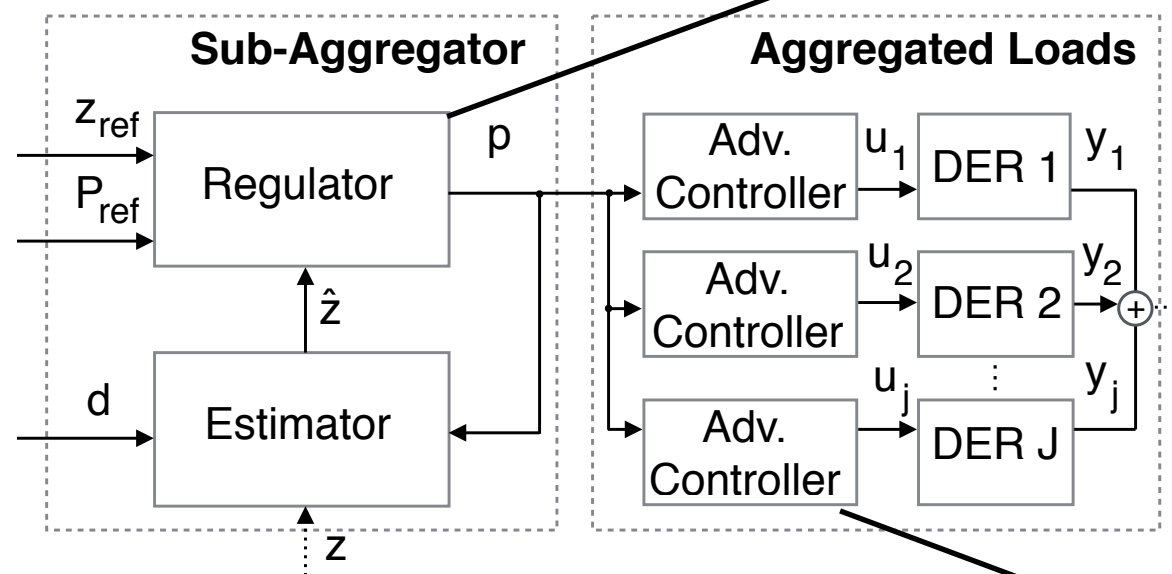
I. A **control problem** at the sub-aggregator level, to determine the appropriate Control (Price) signal to address ancillary services issues.

II. A **model-predictive control** at the consumer's level acting upon receiving the control signal.



Proposed methodology

Control-based methodology



$$\min_p \quad \mathbb{E} \left[\sum_{k=0}^N w_{j,k} \left| \hat{z}_k - z_{ref,k} \right| + \mu \left| p_k - p_{ref,k} \right| \right]$$

$$\text{s.t.} \quad \hat{z}_{k+1} = f(p_k)$$

We adopt a control-based approach where the **price** becomes the driver to **manipulate** the behaviour of a certain pool flexible prosumers.

$$\min_u \quad \mathbb{E} \left[\sum_{k=0}^N \sum_{j=1}^J \phi_j(x_{j,k}, u_{j,k}, p_k) \right]$$

$$\text{s.t.} \quad x_{k+1} = Ax_k + Bu_k + Ed_k,$$

$$y_k = Cx_k,$$

$$y_k^{\min} \leq y_k \leq y_k^{\max},$$

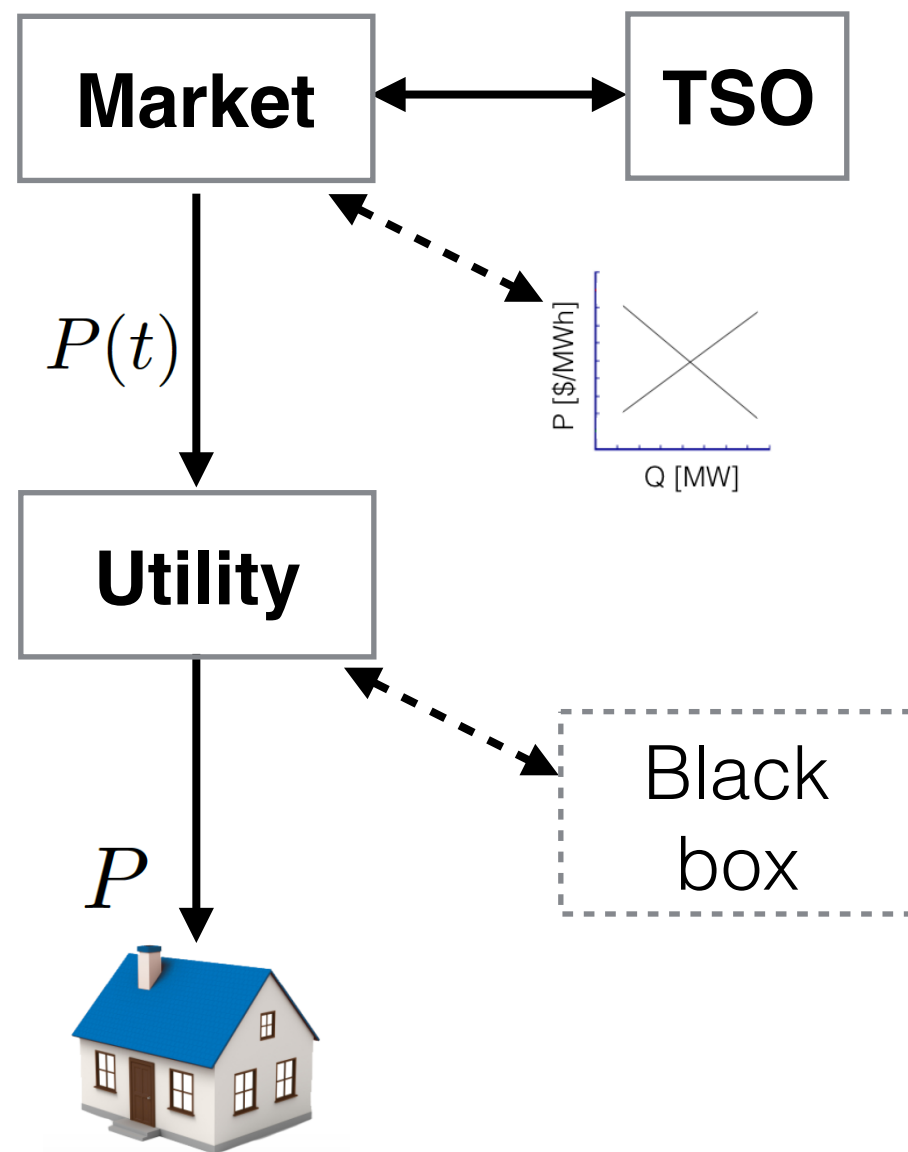
$$u_k^{\min} \leq u_k \leq u_k^{\max}$$



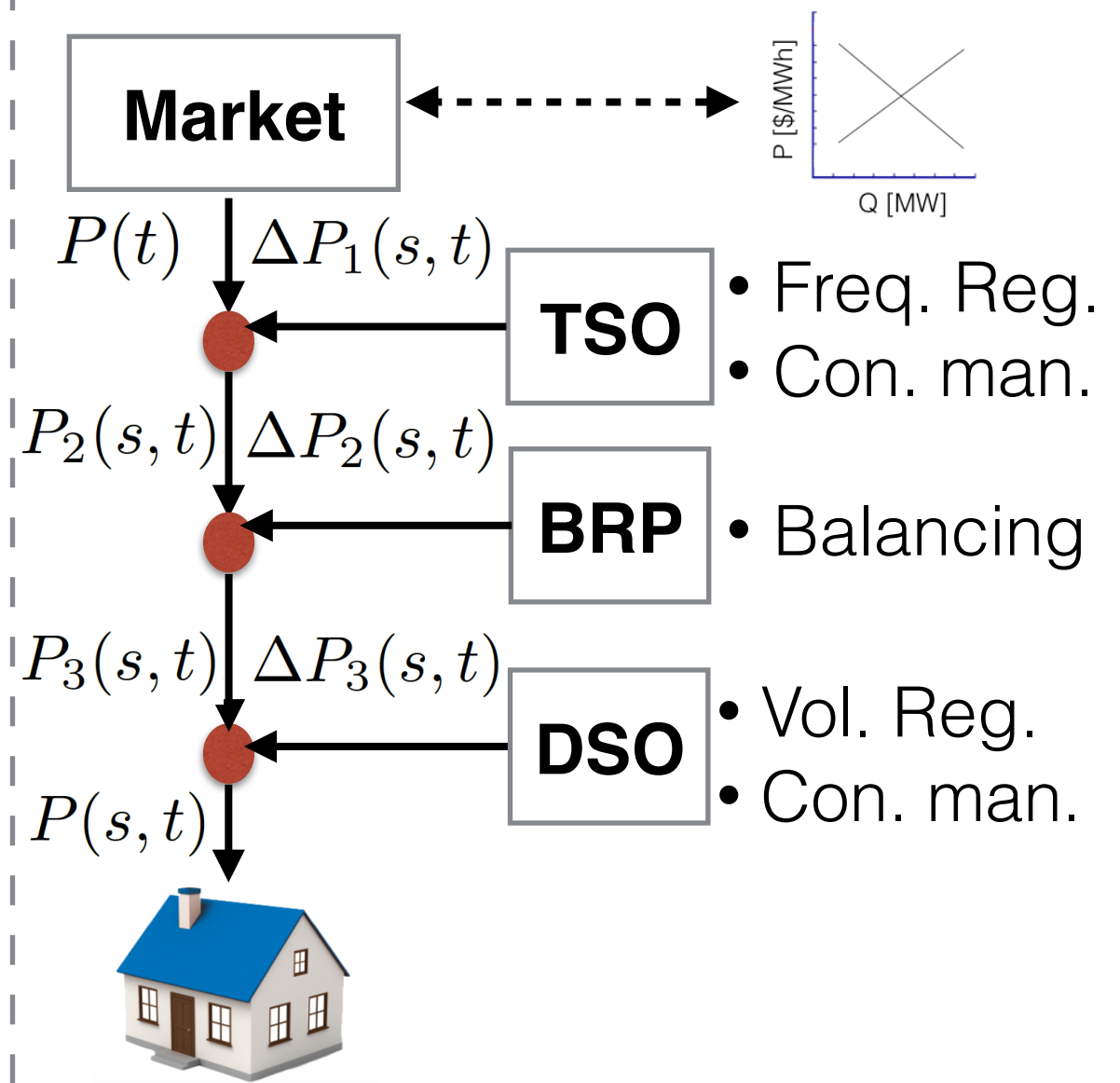
Proposed methodology

Structures for the electricity price

Current structure



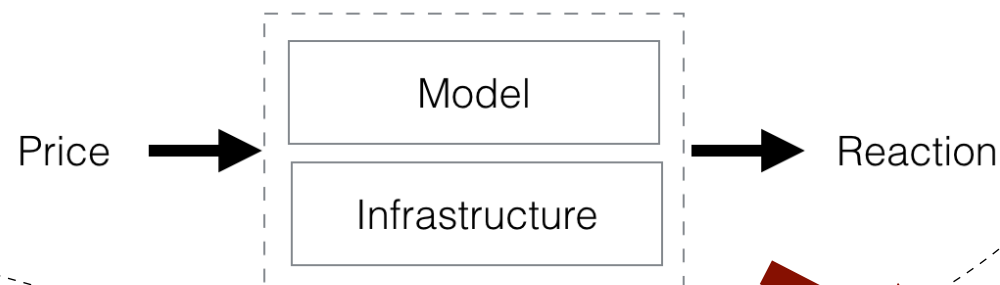
Proposed structure



Proposed methodology

Formulating the delta-prices

Understanding how the consumer reacts according to the price



Prosumers' model

Identifying the delta-prices

$$\Delta P(s, t)$$

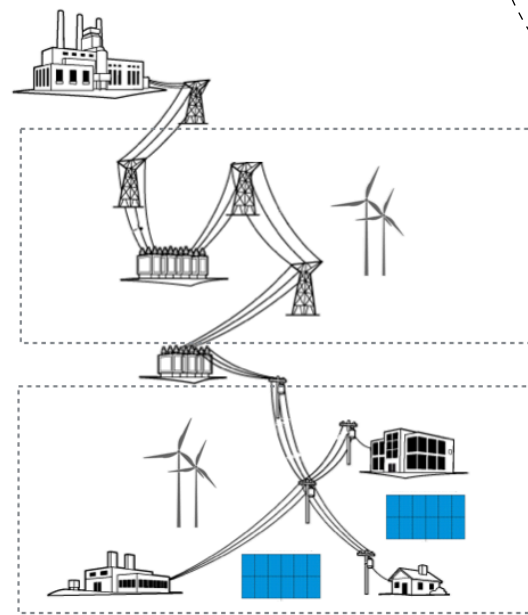
Price

CBA

Running the optimisation problem including the operational constraints

Defining the challenges of the grid and the objective to provide as ancillary services.

Objective function



Main advantages of the proposed methodology

Several advantages can be identified for such methodology:

- It takes into account **stochasticity**, **non-linearity** and **dynamics**.
- It is able to **solve** all the **ancillary services' problems** in **one set**.
- It exploits the **potential** of flexible resources at the prosumers' level of **any size**.
- It is **fast** and fully **automated** at different levels.
- It facilitates the **integration** of the different energy carriers.

Main concerns to be addressed

However, some concerns still need to be addressed:

Model identification

How to identify a **reliable model of the prosumers?**

- Simulations
- Historical data
- Smart meters
- EMPC controllers

Competing delta-prices

How to deal with different delta-prices that intend to achieve **opposite objectives?**

- Different space- time
- Priority of services (frequency) through the use of indices
- Simulations to study stability

Conclusions

We present a **control based-approach** to solve the ancillary services problem in smart grids.

Such methodology is able to **solve all the problems in one set**, taking into account stochasticity, non linearity and dynamics.

We also suggest a change in the formulation of the **retail electricity price**, generating delta-prices that can replace the AS market.

Future **simulations** will test the stability of the method.

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