Smart models for integrating flexibility resources

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Contents

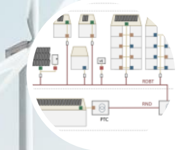
Context

Development of **low-carbon technologies** from generation to end-use)

Deployment of **DES based on renewables** (not controllable → uncertainty associated to forecasts)

Dissemination of **EVs and stationary ESS**

Regulations for **NZEBs**



Development of **energy communities**

Empowerment of consumers as **prosumagers**

Resource Adequacy

Crucial for guaranteeing the **stability** and **resilience** of electrical grids

Variable from country to country

Dependent on national specificities such as **energy mix** and **climatic variability**

Each **country decides**, based on their **needs**:

- the preferred mechanism for ensuring resource adequacy;
- the quantities to be purchased.

Until now ensured by **traditional generation assets**

Resource Adequacy

Crucial for guaranteeing the **stability** and **resilience** of electrical grids

Variable from country to country

Dependent on national specificities such as **energy mix** and **climatic variability**

FLEXIBLE RESOURCES:

distributed renewable generation, manageable resources, stationary energy storage systems, electric vehicles

Each **country decides**, based on their **needs**:

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FLEXIBILITY

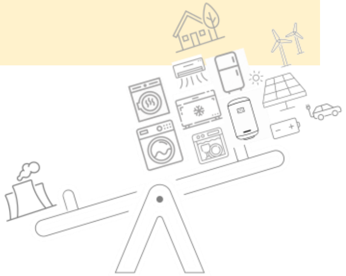
can contribute to a clean electrification and a more efficient energy system

Participating Assets and Flexibility

Inclusion of **flexible resources** into **different markets** will allow prosumagers to monetize their assets

The size of household's flexibility is not sufficiently large to be traded individually

→ **Flexibility** needs to be collected and managed by an intermediate entity between the end-users' resources and the markets – **AGGREGATOR**



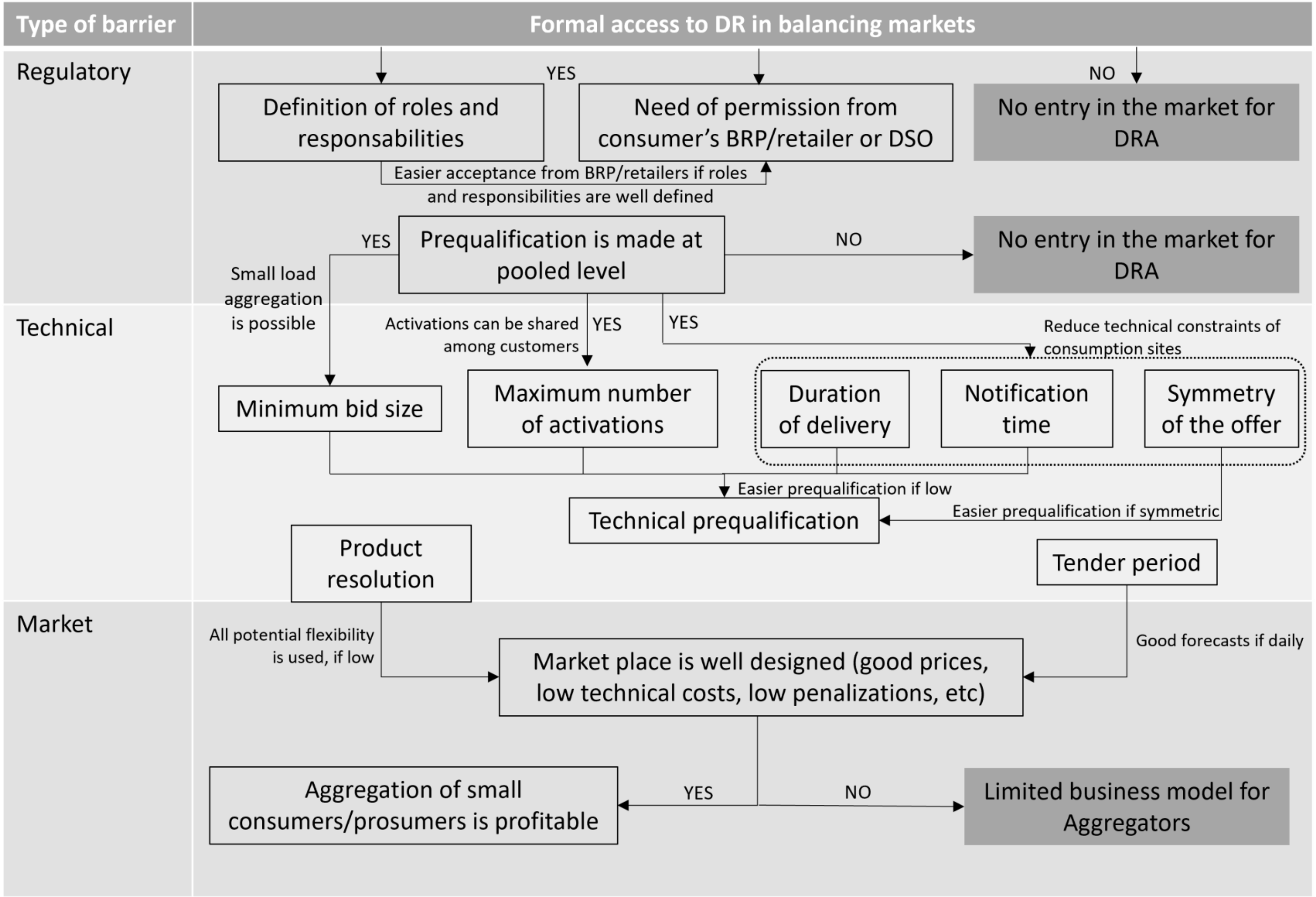
DR programs can be used for activating the household's responsiveness

How? Through price/incentive signals

End-users' response dependent on several factors (e.g., willingness to accept some loss of comfort)

The **aggregator uses** the **aggregated** demand-side **flexibility** of households **to offer market bids**

Barriers for Demand Response Aggregators in Balancing Markets



Smart Models

Bilevel problem:

Aggregator
- Maximize profits

End-user
- Minimize electricity bill
- Maximize comfort

Smart Models

Bilevel problem:

Energy Community

- Minimize procurement costs for serving the load under its responsibility

Retailer

- Maximize total welfare

Smart Models

Bilevel problem:

Aggregator

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Smart Models

Bilevel problem:

DSO

- Minimize operation cost of the distribution system

End-user

- Minimize electricity bill
- Maximize comfort

Smart Models – is there a general structure?

Direct **distributed energy resources** participation

- Linear programming problem solved by the market operator for maximizing the total welfare

Management through set-points or through price signals by a **monopoly non-profit local energy community**

- Upper-level problem describes the local energy community market problem

  Minimize the procurement costs for serving the load under its responsibility

- Lower-level problem describes the market clearing process as performed by the market operator

  Maximize the total welfare

Management through set-points or through price signals by a profit-maximizing monopoly aggregator

- Upper-level problem describes the aggregator local market problem

  Maximize profits

- Lower-level problem describes the market clearing process as performed by the market operator and the decision-making process of the DERs

  Maximize the total welfare

Smart Models – is there a general structure?

Upper-level decision maker: aggregator. Maximize profits.

Lower-level decision makers: end-users. Minimize the overall cost.

Multiple followers with different consumption profiles and willingness to engage in demand response

Aggregator: *max profit*

by determining the remuneration schemes to prosumers (and possibly load control actions)

s. to technical constraints (e.g., power balance, voltage limits, line capacity)

aggregation business regulatory constraints

market clearing

Prosumers: *min overall cost*

by making the integrated optimization of all energy resources (e.g., load shifting, load curtailment, thermostat setpoints, etc.)

s. to demand satisfaction for a given quality of service level (hot water temperature, time slots for operation of shiftable loads, indoor temperature, state of charge of electric vehicle battery, etc.)

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profit = revenue obtained from responding to market operator or system operator requests for upward or downward flexibility (grid services) + fees collected from the prosumers for facilitating their flexibility provision (access to markets) – remuneration paid to prosumers for the flexibility used – compensation for the direct control of some energy resources (e.g., energy storage systems).

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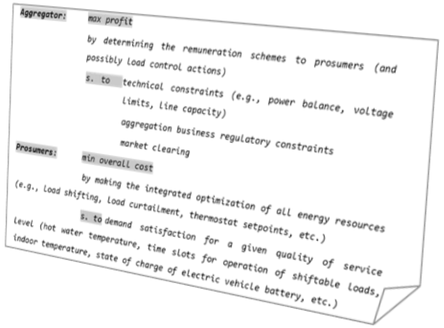
overall cost = electricity bill (energy + power component) in the retail market – remuneration received from the aggregator for the flexibility used (discounted from facilitation fees) – compensation for direct load control of energy resources.

Smart Models – is there a general structure?

General structure can be adapted to the situations in which the aggregator is also a retailer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The **aggregator** may be contractually allowed to control some prosumager's assets (e.g., storage systems) and not all changes in consumption patterns need to be transformed into aggregator's bids.

In addition to the profit objective function, the aggregator may also consider a **fairness objective** to account for a more reasonable distribution of flexibility provision among the prosumagers.

Smart Models – is there a general structure?

Upper-level decision maker: aggregator. Maximize profits

Lower-level decision makers: markets. Maximize social welfare

Aggregator: *max profit*

by determining reserve commitments in reserve markets, bids in day-ahead energy and reserve markets, integrated optimization of energy resources (load management, storage, local generation)

Markets: *max social welfare (market clearing)*

by determining day-ahead energy and reserve prices, reserve schedule, power schedule

- **Different market configurations** can be considered
- In general, **energy bids** are cleared in the day-ahead market by the market operator and reserve bids are cleared and deployed in real time by an independent system operator (ISO)
- **Aggregators are usually remunerated** by the deployed reserves in real time only and are subject to penalties due to energy imbalances and reserves not supplied

Conclusion

Ongoing change of the conventional paradigm of ***supply follows demand***, in which generation was adapted to consumption evolution, into ***demand follows supply***, in which demand is modulated to variable supply

Renewable energy generation is not controllable

The **increase of energy consumption** to satisfy comfort needs and supply new significant loads (as electric vehicles) brought higher demand peaks and grid congestion, which may require costly grid reinforcements

FLEXIBILITY

in consumption patterns offered by end-users through DR mechanisms can play an important role

→ Empowerment of consumers/prosumers who can have a more proactive role in system management and efficiency

Conclusion

AGGREGATORS emerge in this context as entities which can help identifying and materializing the flexibility potential, including the coordination of distributed energy resources and manageable loads

Aggregators **automate the provision of flexibility** for different aims, through their participation in electricity markets and services provision, as well as delivering risk management products and suitable contracts for companies and other combined services to their clients

Several studies have been focusing on the de**velopment of business models and operational optimization models for aggregators**, typically aiming at maximizing their profit

Bilevel stochastic programming has been widely used, recognizing both the hierarchical decision structure (aggregator vs. consumer, aggregator vs. markets / system operators) and the multiple uncertainty factors at stake to reach robust decisions

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