Flexibility – the Danish case

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Outline

• What is flexibility?

• Tools and effectiveness

• Examples from Danish projects:
  – At transmission level: **ACES** → electric vehicles controlling the frequency
  – At distribution level: **Ecogrid 2.0** → heaters controlling the power consumption locally
  – At customer level: **Insulae** → reconfigurable storage for smoothening EV fast charging

• Lessons learned
What is flexibility? A definition

The ability of power system operation, power system assets, loads, energy storage assets and generators, to change or modify their routine operation for a limited duration, and responding to external service request signals, without inducing unplanned disruptions.

M. Z. Degefa, I. B. Sperstad, H. Sæle, "Comprehensive classifications and characterizations of power system flexibility resources," EPSR, vol. 194, 2021

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Figure 1: (a) Theoretical and (b) practical attributes of a flexibility service (excluding the location).

Flexibility tools and their effectiveness

Table 1. An assessment of the different mechanisms for unlocking flexibility in renewables-based power systems with flexible demand.

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Effectiveness on Congestion Management</th>
<th>Ease of Implementation</th>
<th>Market Compatibility</th>
<th>Impact on System Balancing</th>
</tr>
</thead>
<tbody>
<tr>
<td>ToU Tariffs</td>
<td>Low (T, D, F)</td>
<td>High (T, D, F)</td>
<td>High (T, D, F)</td>
<td>Negative</td>
</tr>
<tr>
<td>Dynamic Tariffs</td>
<td>Low (T)</td>
<td>Medium (T, D)</td>
<td>Medium (T, D, F)</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Medium (D, F)</td>
<td>Low (F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finer Geographical Granularity</td>
<td>High (T, D, F)</td>
<td>Medium (T)</td>
<td>Medium (T)</td>
<td>Neutral</td>
</tr>
<tr>
<td></td>
<td>Low (D, F)</td>
<td>Low (D, F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilateral Agreements</td>
<td>High (T, D, F)</td>
<td>Medium (T, D)</td>
<td>High (T, D, F)</td>
<td>Negative</td>
</tr>
<tr>
<td>Local Flexibility Markets</td>
<td>High (T, D, F)</td>
<td>Medium (T, D, F)</td>
<td>High (T, D, F)</td>
<td>Neutral</td>
</tr>
</tbody>
</table>

Key: T: transmission; D: distribution; F: feeder.

The test-bed where flexibility tools were tested – the island of Bornholm

https://bornholm.powerlab.dk/
The ACES project
Across Continents Electric vehicles Services

Budget: 10 MDKK (=1.4 M€)
Public grant (EUDP): 55 %
Equivalent person-months:
130 over 3.5y (04/17-09/20)
Public chargers and EVs used in the demo:
20 Nissan Leaf and env-200

www.aces-bornholm.eu

Project final event streamed online and slides available:

https://youtu.be/W-pd_11svQ

https://drive.google.com/drive/folders/1tqGiPWKTajSpm_hoMgp7Kszhb2LZOnyJ?usp=sharing

Electric vehicles (EVs) providing frequency control in a centralized manner

- Frequency provision provided on a commercial basis
- 21 EVs with 10 kW bidirectional chargers provide frequency overnight (16-6) during weekdays and the whole day in the weekend.

1 year of PFC:
- 40 kWh
- 15 hours
- ±10 kW

<table>
<thead>
<tr>
<th></th>
<th>Capacity payment</th>
<th>1400 €/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity costs*</td>
<td>200 €/y</td>
<td></td>
</tr>
<tr>
<td>= Revenue</td>
<td>1200 €/y</td>
<td></td>
</tr>
</tbody>
</table>

Ecogrid 2.0 project in numbers

• Timeframe: 42 months (Jan 2016 until June 2019)
• Budget: 98 million DKK (=13 M€)
• Founded by EUDP (Danish development fund) EcoGrid 2.0 is built on the experiences with price signals in the first project, EcoGrid EU.
• www.ecogrid.dk
• The 9 partners in the project:
Ecogrid 2.0 project results – capacity vs baseline services

• The design of the local flexibility market products is crucial. A large part of the project focused on service definition and the associated impact.

• Two types of services:

  - **capacity**

  ![capacity_diagram]

  - **baseline**

  ![baseline_diagram]

Ecogrid 2.0 project results – an example of DSO service (aggregation of units)

Request of flexibility: 100 kW for 1 h;
On average 0.5 kW heat units
Response rate (statistically 90%)
The flexibility depends heavily on the time of the day and the outdoor temp.
Baseline service is easier to realize compared to power limitation (capacity) because it does not require observability at the transformer.

H2020 Insulae – decarbonizing islands

- 10 M€ funding from EU
- 4 years (2019-2023)
- 26 partners
- 3 demo islands
- 4 follower islands

- (UC1) joint management of hybridized RES and storage,
- (UC-2) Smart integration and control of water and energy systems,
- (UC-3) Empowerment of islands’ energy communities through 5G and IoT technologies for flexibility services,
- (UC-4) Transition to DC grids,
- (UC-5) Local bio-based economies supporting the electrical, thermal and transport systems integrated management,
- (UC-6) Electrification of the islands’ transport looking to grid frequency and voltage regulation and
- (UC-7) Storage and power electronics for the stabilization of weak grids and microgrids.
H2020 Insulae – one of the Danish demonstrations

- 104 x 3 kWh reconfigurable LiFePo4
- 60 kW PV
- 43 kW grid connection
- 2x175 kW EV chargers


Lessons learned

1. With the current low energy prices and high equipment costs, the resulting small payments per flexibility make it challenging to establish business models (frequency control is a partial exception).

2. Standardization is widely recognized as a key requirement for improving the economic attractiveness of flexibility procurement. A coordinated effort on a European level is underway to harmonize TSO practices, regarding the monitoring, validation, and standardization of communication.

3. DSOs are expected to play a pivotal role in this transition to a DER-dominated power system.

4. The substantial increase in electricity demand and the amount of flexible demand that follows the volatile power market prices pose a threat in the security of the supply of end-users unless costly grid reinforcements are undertaken.

5. Demand-side flexibility can turn this challenge into an opportunity by creating new value streams, given that the appropriate framework is in place.
References


