Flex-Offers: Unified handling of Flexibility in Electricity Consumption and Production

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THE FLEX-OFFER CONCEPT
Flexible Electricity Consumers and Producers

Flexible Offer (flex-offer) allows unified modelling of a flexible consumer/producer in ALL these cases

- No or simple flexibility patterns
  - No flexibility
  - Time-shift flexibility
  - Time-shift flexibility
  - Amount flexibility
  - [Total Amount requirement]

- Complex flexibility patterns
  - Amount flexibility with intra-time unit dependencies

Flexible Offer (flex-offer) allows unified modelling of a flexible consumer/producer in ALL these cases

\[ \text{totalMinEnergy} \leq \sum_{t} e_t \leq \text{totalMaxEnergy} \]
all the examples are from households, perhaps you could add a few for the industrial/commercial cases we have eg in Arrowhead

Torben Bach Pedersen; 1.11.2016
Flex-Offer Aggregation and Disaggregation

Aggregation → Scheduling → Disaggregation

Prosumer flex-offers → Scheduled prosumer flex-offers
(Simple or Aggregated) Flex-Offer Lifecycle

Legend:
Demand Response event in Mirabel
FlexOffer parameter set by Prosumer
Ability to dispatch for BRP
(Simple or Aggregated) Flex-Offer Lifecycle

- **Start time**
- **Flex-Offer Schedule**
- **Generate ON/OFF signals to fulfil the schedule**

**Time**
09:00 09:15 09:30 09:45 10:00 10:15 10:30 10:45 11:00

**kW**
10 20 30

**Utility Company**

- **Prosumer**
- **Negotiation**
- **Planning**
  - **Assignment**
  - **Scheduling**
- **Control**
  - **Execution**
- **Billing**
  - **Incentive**

*(One feasible)*

<table>
<thead>
<tr>
<th>v_1</th>
<th>v_2</th>
<th>v_3</th>
<th>v_4</th>
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<tbody>
<tr>
<td>10</td>
<td>20</td>
<td>30</td>
<td>20</td>
</tr>
</tbody>
</table>
(Simple or Aggregated) Flex-Offer Lifecycle

Customer: arrowhead_lift

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
<th>Price</th>
</tr>
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<tbody>
<tr>
<td>Number of flexoffers</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Fixed reward for all flexoffers</td>
<td></td>
<td>10.00 DKK</td>
</tr>
<tr>
<td>Total Time Flexibility</td>
<td>0 time units (15 min)</td>
<td>0.00 DKK</td>
</tr>
<tr>
<td>Total Energy Flexibility</td>
<td>68.83 kWh</td>
<td>6.88 DKK</td>
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<tr>
<td>Number of default schedule deviations</td>
<td>0</td>
<td>0.00 DKK</td>
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<tr>
<td>The sum of stat time scheduling deviations with respect to the default schedule</td>
<td>0 time units (15 min)</td>
<td>0.00 DKK</td>
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<tr>
<td>The sum of energy deviations with respect to the default schedule</td>
<td>0.00 kWh</td>
<td>0.00 DKK</td>
</tr>
<tr>
<td>Total Reward</td>
<td></td>
<td>16.88 DKK</td>
</tr>
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</table>
**Flex-Offers**: A Powerful Concept Applicable in Many Smart-Grid Applications:

- Demand supply balancing
- Electricity trading
- Congestion management
- ...
USING FLEX-OFFERS BOTH FOR ELECTRICITY AND DISTRICT HEATING
Flex-Offers for electricity and heating

**Observation 1:** kW and kWh can be used for both electrical and thermal energy, and so can Flex-Offers

**Observation 2:** Flex-Offers for different types of energy should be treated separately

**Observation 3:** For interplay, energy conversion needs to be modelled as a flex-offer

E.g., A house heated with a heat-pump and comfort constraints

Temperature $x(t)$,

$$\theta_r - \delta \leq x(t) \leq \theta_r + \delta$$

Heater power $u(t)$,

$$0 \leq u(t) \leq P$$
Example of modelling energy conversion

1. Linear Time Invariant State Space Model

\[ x(t) = \left(1 - \frac{1}{R \cdot C}\right) \cdot x(t-1) + \left(\frac{\eta}{C}\right) \cdot u(t) + \left(\frac{\theta_a}{R \cdot C}\right) \]

Constraints on input and state

\[ 0 \leq u(t) \leq P \]
\[ \theta_r - \delta \leq x(t) \leq \theta_r + \delta \]

2. Exact polyhedrons

3. FO with Energy Flexibility

4. FO with Energy Flexibility and Dependencies

- R – thermal resistance (°C/kW)
- C – thermal capacitance (kWh/°C)
- η – coefficient of performance
- θ_a – ambient temperature (°C)
- θ_r – required temperature (°C)
- δ – user temperature band (°C)
FLEX-OFFER RELATED PROJECTS AND MAJOR ACHIEVEMENTS
Related Projects/Initiatives

2010-2013

**MIRABEL**
Balancing energy supply and demand
www.mirabel-project.eu

- Scalable ICT system for:
  - Higher RES integration
  - Demand-supply balancing
  - Flex-offer management

2012-2016

**TotalFlex**
www.totalflex.dk

- Develops and demonstrates a market-based system for flexibility trading and congestion management

2013-2017

**ARROWHEAD**
www.arrowhead.eu

- Largest European automation project of all time
- Collaborative automation and interoperability of networked devices in (1) production, (2) end-user services, (3) smart buildings and infrastructure, (4) electro-mobility, and (5) markets of energy.

2015-2021

**DiCyPs**
CENTER FOR DATA-INTENSIVE CYBER-PHYSICAL SYSTEMS

- Research on how to utilize software and data for smarter solutions in health, traffic, energy, and community service domains

2016-

**GoFlex**

- Will integrate, and demonstrate a group of smart-grid technologies for the cost effective use of demand response in distribution grids
Major results: Hierarchical ICT infrastructure

Flexible demand and supply can lead to 7-13% cost reduction for BRPs.
Flexible demand and supply improves RES integration significantly: 70% of the negative impact of fluctuating renewables can be neutralized if 15% of the energy consumption is flexible and intelligently controlled by the BRP.
Households can reduce energy bills by 10-20%
For all forms of flex-offers, a number of flex-offer (dis-) aggregation techniques were developed: *simple*, *incremental*, with *bin-packing*, with *balancing*.
Major results: Flex-Offer Aggregation

- **Millions of flex-offers** can be aggregated and disaggregated **in seconds**

- **Aggregation+Scheduling+Disaggregation** is **BETTER AND FASTER** than just **Scheduling**

- Aggregated flex-offers of the **desired form** can be generated:
  - “More flexibility NOW”
  - “More flexibility LATER”
  - “Keep balance conditions”
Major results: Flex-Offer Market

PERFORMED AN ANALYTICAL AND EXPERIMENTAL VALIDATION OF FLEXIBILITY IN THE DANISH REGULATION AND SPOT MARKETS:

- On average, **50% of the energy demand** from a **household** is flexible.
- BRPs/Aggregators can achieve **49% reduction** in the regulation cost with just **3.5% of energy demand being flexible**

CONSIDERED FLEXIBILITY PRICING AND DEVELOPED A MARKET FOR FLEXIBILITY (FLEX-OFFERS)
Major results: Flex-Offer Market

DEFAULT SCHEDULE AND PRICES FOR ΔKWH:

Time interval 11:00-11:15
Major results: Flex-Offer Market

Flexibility Trading: 11:00-11:15

- Existing electricity markets
- Market Place for flexibility
- Buying flex-offer
- Selling flex-offer

Diagram showing interactions between DSO, TVPP, Electricity company, Aggregator, CVPP, and BRP.
Summary

FLEX-OFFERS

- Powerful concept for unified modelling of flexibility
- Suitable for negotiation, planning/trading, control, and billing
- Validated in a number of Danish and EU projects

Key References

- Matthias Böhm, Lars Dannecker, Andreas Doms, Erik Dovgan, Bogdan Filipic, Ulrike Fischer, Wolfgang Lehner, Torben Bach Pedersen, Yoann Pitarch, Laurynas Siksnys, Tea Tusar: Data management in the MIRABEL smart grid system. EDBT/ICDT Workshops 2012: 95-102
- Luis Lino Ferreira, Laurynas Siksnys, Per Pedersen, Petr Stluka, Christos Chrysoulas, Thibaut Le Guilly, Michele Albano, Arne Skou, César Teixeira, Torben Bach Pedersen: Arrowhead compliant virtual market of energy. ETFA 2014: 1-8
THANK YOU!
Background

Renewable Energy is challenging:

Solution: Make demand and supply flexible
**Use-case Example**

1. A consumer arrives home at 10pm and wants to recharge the electric vehicle's battery at the lowest possible price by the next morning.

2. The consumer’s LEDBMS generates a FO:

3. A negotiation with the BRP/aggregator is started:

4. The consumer is rewarded for its offered flexibility
Major results: Flex-Offer Aggregation

\[ t_{es} = \min (s_{f1}, s_{f1}, s_{f1}) \]

\[ tf(fA) = 1 \]
FlexOffer Management Platform

- Flexibility market approach
- Evaluation of flexibility value in energy regulation markets
- Cost-effective FlexOffer scheduling techniques for energy balancing
- Integrated system for FlexOffer data prescriptive analytics and management
- Algorithms for predicting grid congestions
- Scalable techniques for aggregating FlexOffers and disaggregating FlexOffer schedules
- Techniques for balancing energy and avoiding grid congestions during FlexOffer aggregation
- Techniques for flexibility extraction from the smart-meter measurements
- Techniques for flexibility detection and extraction at the appliance levels

www.arrowhead.eu