Pilot B (Denmark)

Flexibility in Summer Houses with a Swimming Pool

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DTU Compute

Florence SmartNet Workshop, October 24th - 26th, 2018

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691405
Overview of Pilot B

Description:
- 30 Summer houses with a swimming pool – and either boilers or heat pump.
- Indirect control using price (or other penalty signals)
- One way communication

Extension:
- **CO2-base control** since May 2017 for demonstrating how to accelerate the transition to a low fossil future.
- **DSO congestion** based on real-time measurements for better integration of PV, EV and Heat Pumps
- Optimize the end-user **flexibility** for the best **integration of wind and solar**

Functionalities:
- **Aggregation of information every 5 minutes** and presented via the SmartNet WEB interface.
- **CO2-based control** since May 2017.
- **Price-based control** since beginning of January 2018.
- **Estimation and forecasting of 5-min balancing prices.**
- Data exchange between ‘TSO’ and Economical Aggregator (ONE) established
- Data exchange between Eco. Aggregator and Tech. Aggregator (ENFOR) established
- **Flexibility concepts for smart grid applications established.**
- Common TSO-DSO market setup established
Pilot B
Introduction
Smart-Energy OS

Maximizes the flexibility – Simple communication – No contracts

Described in Wiley Book, DTU Annual Report, and several IEEE papers
Overview Pilot B

SmartNet

1. Receive Grid Load
2. Calculate residual capacity
3. Receive bids
4. Clear market
5. Activate bids
6. Send price signal incl. forecast
7. Measurements
8. DER trading system

Ancillary services
- Frequency control
- Congestion management
- Voltage control

TSO Trading System
EMS-SCADA
Transmission System Operator [TSO]

Local services
- Local Frequency control
- Local Voltage control
- Congestion management

DSO Trading System
DMS-SCADA
Distribution System Operator [DSO]

Market Operator [MO]
- Day-ahead
- Intraday
- Real-time

Energy trading and portfolio management
- CMP Trading System
- EMS-SCADA
- Commercial Market Party [CMP]

Technical aggregation
- DER services
- Value Added services
- DER Aggregator

High Voltage Sub-station
Primary Sub-station
Secondary Sub-station

Distributed Energy Resources
DER gateway
DER trading system
Pilot B (short summary)

The SmartNet Technical Aggregator at ENFOR is designed such that we can shift between any external ‘penalty signal’. We are able to shift to any ‘penalty signal’ with a very short notice.

Have been up and running with CO2-based control since May 2017.

Shifted to price-based control on January 4th, 2018 – using 5 min balancing prices from ENFOR.

Flexibility function for price-based control is estimated for the aggregated consumption, and ONE has been able to send the prices to ENFOR (Technical Aggregator).

We have learned a lot about how to establish a cloud-based control of smart buildings – and in such a way that they can support the future smart grid (eg. Voltage control and congestion management also in DSO areas).

Danish Pilot participated in the HiL simulation test (WP4.5) with AIT.
Figure 2: The energy consumption before and after an increase in penalty. The red line shows the normalized penalty while the black line shows the normalized energy consumption. The time scale could be very short with the units being seconds or longer with units of hours. At time 2.5 the penalty is increased,
Penalty Function (examples)

- **Real time CO₂.** If the real time (marginal) CO₂ emission related to the actual electricity production is used as penalty, then, a smart building will minimize the total carbon emission related to the power consumption. Hence, the building will be *emission efficient*.

- **Real time price.** If a real time price is used as penalty, the objective is obviously to minimize the total cost. Hence, the building is *cost efficient*.

- **Constant.** If a constant penalty is used, then, the controllers would simply minimize the total energy consumption. The smart building is, then, *energy efficient*.
Smart Grid Applications

Figure 8: Smart buildings and penalty signals.
Pilot B
Upper Level
Evonet’s supply area

- Supply area in Syd- og Sønderjylland and a part of Nordjylland
- Created through 26 mergers
- Supply of app. 324,000 installations
- A part of SE-koncernen
Example: DSO challenges

The load rate of the grid
Pilot B Upper Level
- Time line for bids and activation

\[ \text{Bids / price [€/MWh]} \]

- ENFOR: DK1 Imbalance Price Consumption \textbf{Pred} 5-min (period 0 - 5 min)
- ENFOR: DK1 Imbalance Price Consumption \textbf{Sim} 5-min (period 1 - 5 min)

\[ \text{T[-1]: Activations for period [0:5] are sent} \]
\[ \text{T[-4]: Deadline for placing bids for period [0:5]} \]
Pilot B
Lower Level
How does it work?

Data measurement and information gathering

SN-10 backend

DTU/ENFOR backend

SmartNet
How does it work?

Price based Control

SN-10 backend

DTU/ENFOR backend
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Share of electricity originating from renewables in Denmark Late Nov 2016 - Start Dec 2016

Source: pro.electricitymap.org
Example: Price-based control
Example: CO2-based control
Example with negative power prices

From 3 am to 11 am we had a longer period with a negative imbalance power price, and consequently the SmartNet controllers took advantage of the negative price period and 'earned' money by overheating the pools.

Hence the system helped the power system by storing extra energy in the pools - for later use.

One example is House No. P32788. This house reached the max. temperature which in this case is 30 d.c.
The SmartNet Technical Aggregator at ENFOR is designed such that we can shift between any external 'penalty signal'. We are able to shift to any ‘penalty signal’ with a very short notice. It can be energy efficient, price efficient or emission efficient. Have been up and running with CO2-based control since May 2017 and price-based control since January this year.

A real clearing platform is established with connection from our ‘TSO’, DSO, Aggregator and the Technical Cloud-based Aggregator/controller

We have learned a lot about how to establish a cloud-based control of smart buildings – and in such a way that they can support the future smart grid (eg. Voltage control and congestion management)

Danish Pilot participated in the HiL simulation test with simulations at AIT.

Huge national interest in the Pilot B setup due to similarities with District Heating systems wrt. flexibility

New project with NREL: Here we are simulating a grid with 2000 buildings and using our concepts of price-based control. We have two people at NREL for the moment. Report and papers will be published jointly with NREL.

We presented some of the results of Pilot B at the European Parliament on June 27th, 2018.
DSO Perspectives

Possibilities in the future

- Good price signals important in the balancing of the distribution grid.
- New tariff to support price signals.
- Maybe local tariff is necessary.
- New tariff that can take care of local energy system, which is “off grid”.
- New ways to integrate battery systems into the power grid.
- Use the inverters as voltage stabilizing devices in the grid.
TSO Perspectives

- Automatic solutions targeting small units
- External control of units
- DSO-TSO combined optimization
- Improved flexibility and energy systems integrations
National Perspectives

• SmartNet has created a lot of attention – we are for the moment in close contact with several ministries.

• In general we begin to see issues in DSO grids, and here solutions from SmartNet will be seriously considered.

• Our TSO will talk about SmartNet at an upcoming national meeting. Specifically this talk will focus on how the methodologies can provide the needed flexibility for an integration of more wind power (today we have 44 pct in our power system).

• Pilot B of SmartNet is water in swimming pools heated by heat pumps. One idea is not to use the SmartNet principles for heating the water using heat pumps in our District Heating systems (approx. 70 of buildings are heated by DH).

• Control based methods from SmartNet Pilot B (lower level) as alternative to flexibility markets will be considered by our TSO.
SmartNet-Project.eu

This presentation reflects only the author’s view and the Innovation and Networks Executive Agency (INEA) is not responsible for any use that may be made of the information it contains.
Pilot B
Misc.
Proposed methodology
Control-based methodology

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

s.t. \ \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.
(Virtual) Storage Solutions

- **Flexibility (or virtual storage) characteristics:**
  - Supermarket refrigeration can provide storage 0.5-2 hours ahead
  - Buildings thermal capacity can provide storage up to, say, 5-10 hours ahead
  - Buildings with local water storage can provide storage up to, say, 2-12 hours ahead
  - District heating/cooling systems can provide storage up to 1-3 days ahead
  - DH systems with thermal solar collectors can often provide seasonal storage solutions
  - Gas systems can provide seasonal/long term storage solutions
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