Center for Electric Power and Energy
Department of Electrical Engineering

Residential Demand Response – an iPower view on how it can contribute to a smart grid

Henrik Bindner
iPower Platform Manager,
Senior Scientist, Research Group Leader 'Energy Systems Operation and Management'
Center for Electric Power and Energy

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The Research Council of Norway
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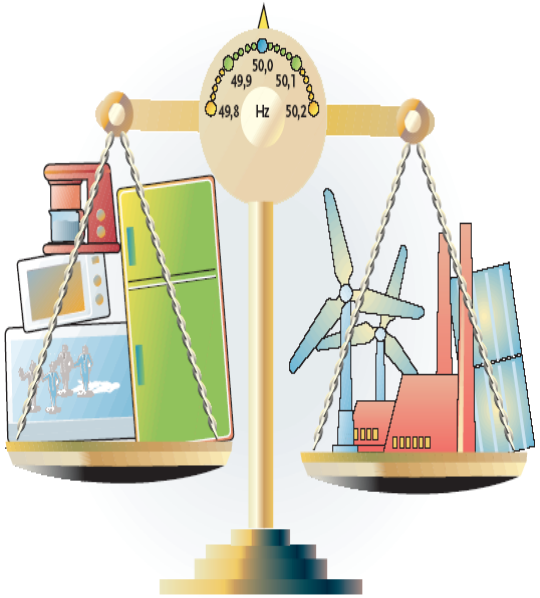
Outline

- What is the problem for the future power system
- Where to look for solutions
- What are the challenges in developing the solutions
- Outline of iPower
- Selected results from iPower
- Conclusions

What’s the problem

- The power system has to be safe, reliable and balanced at all time instances

Balancing the Power System



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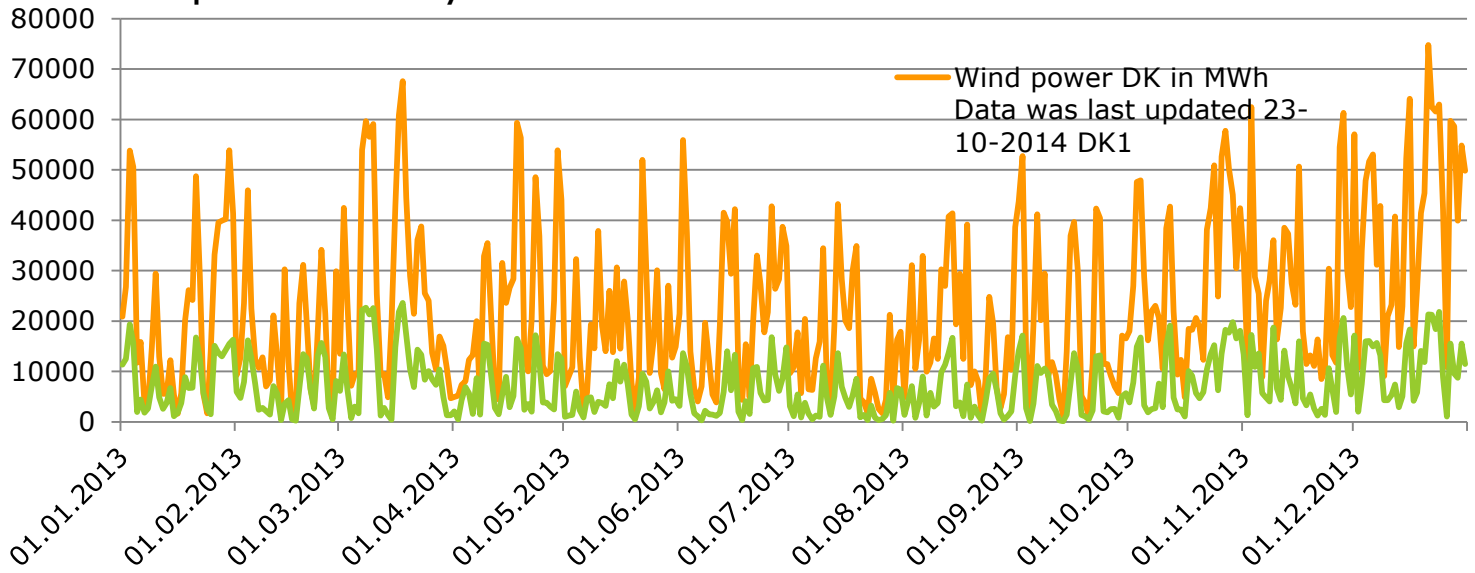
- The fraction of renewable energy will increase as we are moving towards a fossil free system
  - Wind and solar power has inherent fluctuations and limited predictability



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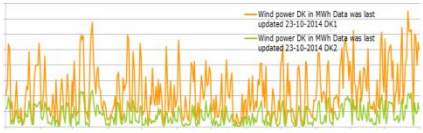
  - Increased consumption and changed consumption pattern



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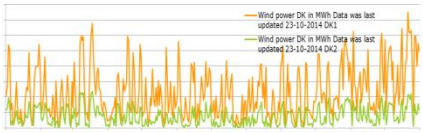
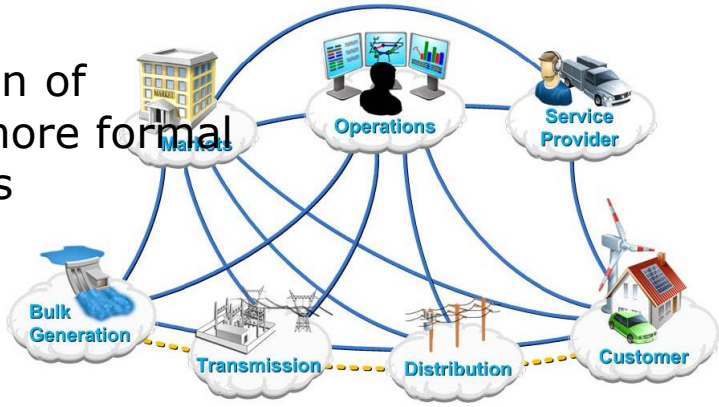
  - Increased consumption and changed consumption pattern
- Operation of the power system will increasingly be market based
  - This means a separation and clarification of responsibilities and a requirement for more formal interaction between the involved parties

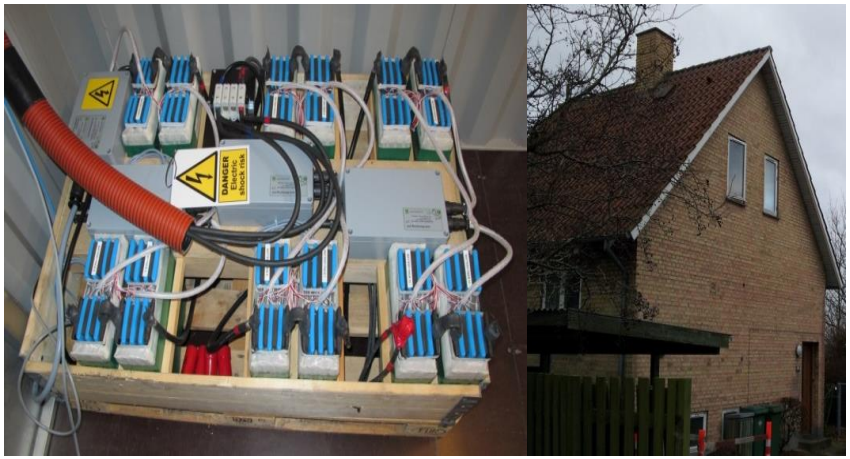




Source: NIST

Where to look for solutions

- Significant fractions of the electricity consumption are associated with some form of intrinsic storage
  - Hot water in the district heating system
  - The heat capacity of buildings, commercial as well as domestic
  - Goods in cold stores
  - Batteries in Electric Vehicles and stationary
- By controlling the electricity consumption the energy storage can provide some of the required flexibility to shape the instantaneous power consumption to the instantaneous power generation
- Power consumption can therefore absorb some of the fluctuations from renewable energy and therefore contribute to enable a power system based on renewable energy



The challenges

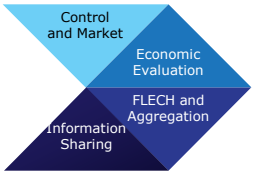
- The challenges include
  - Make owners of potential sources of flexibility aware and interested in making their facilities available for flexibility provision including how to establish positive business cases
  - Develop and demonstrate controllers of single entities e.g. house heating systems or supermarket coolers
  - Make the flexibility of the individual devices available for the system in an operational and economic way e.g. by aggregation
  - Ensure that the grid is operated in a safe and secure way and that contracts are adhered to
  - Implement this in a is feasible and economic way by having well-defined service descriptions and using internationally agreed standards for communication
  - Reach a point where the economic and feasible solution of smart grid and not conventional grid reinforcement

iPower -- a Danish Strategic Platform for Innovation and Research

Strategic Platform for Innovation and Research supported by Innovation Fund Denmark

The five year vision of the iPower platform is to develop an intelligent power system where production controlled demand replaces and supplements demand controlled production.

What is iPower



Domestic Demand Response

Consumer Behaviour

Industrial Demand Response

Distribution Grid Operation

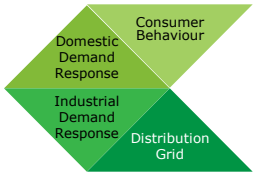
What is iPower

Control and Market Operation

Socio-economic and Investor Evaluation

FLECH and Aggregation

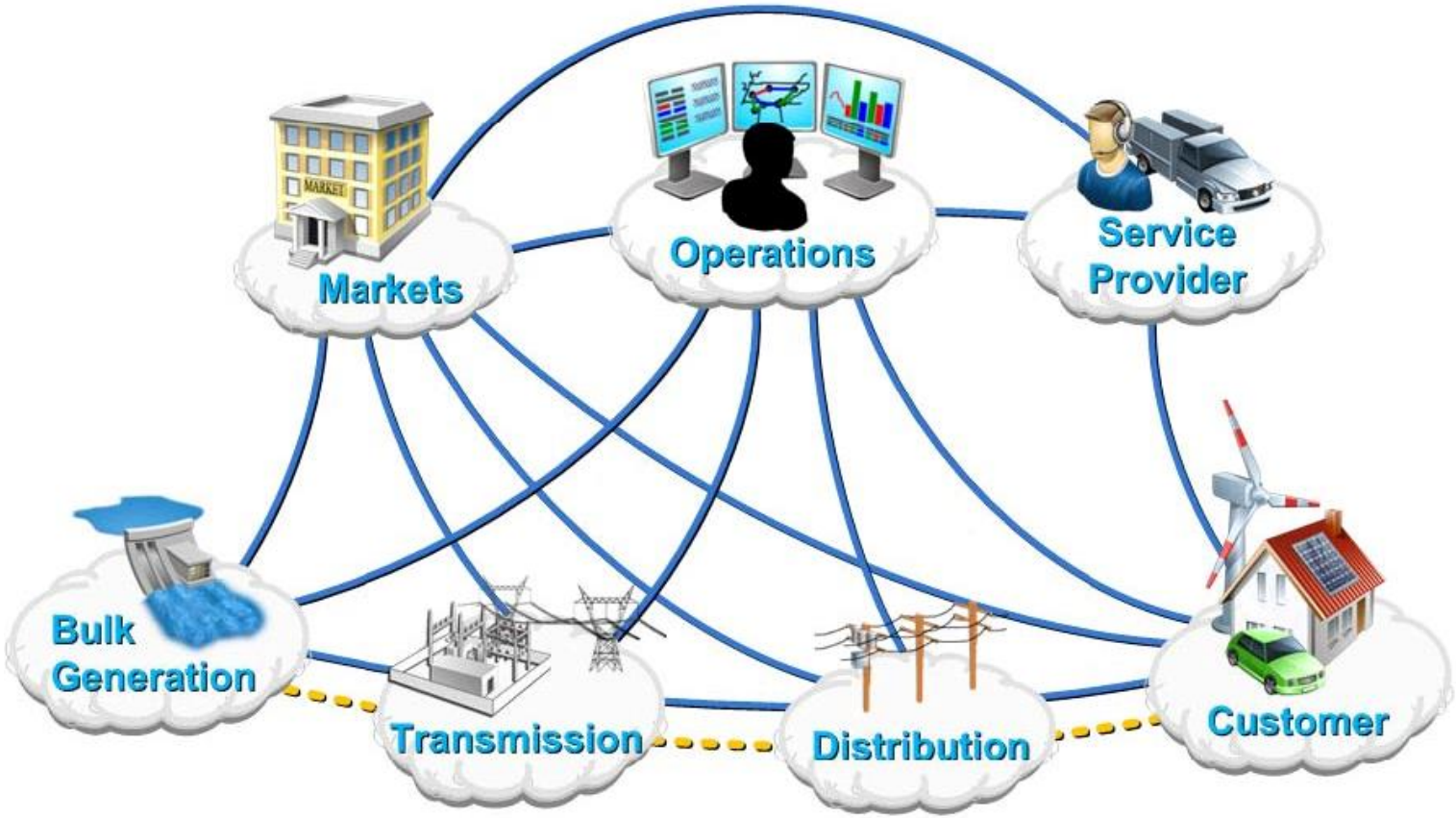
Information Sharing



Partners

26 partners, budget 16 MEUR
Started 2011, ends 2016

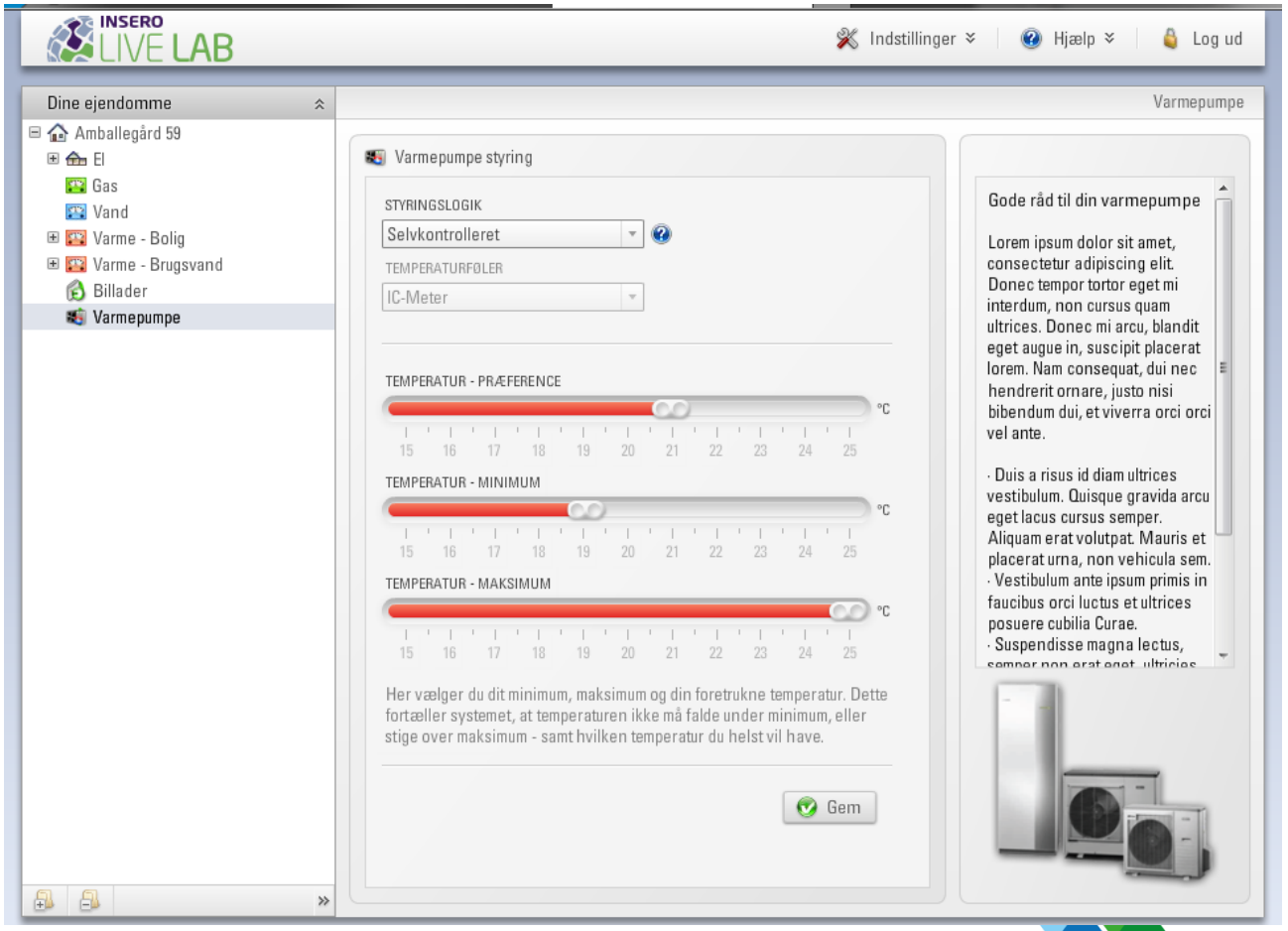
Smart Grid



Source: NIST

User interaction

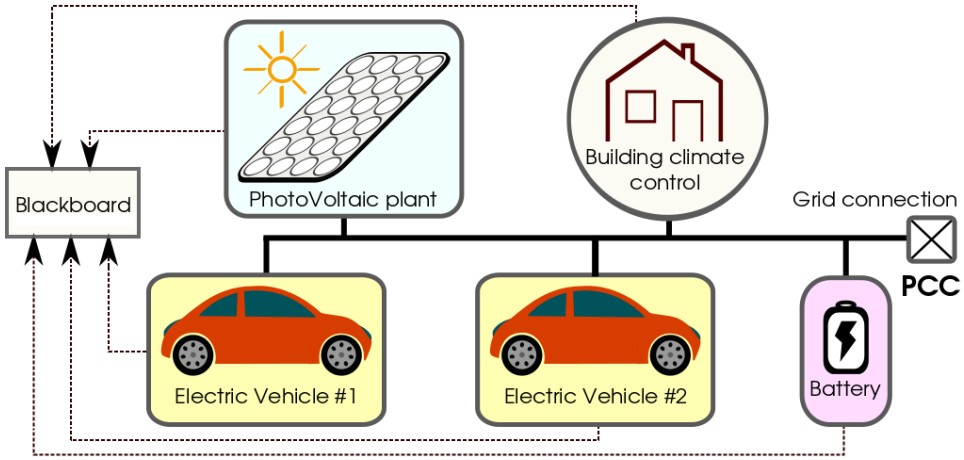
- Different versions of user GUI can be tested on real user to investigate how users can provide most flexibility
- Close collaboration between Saseco, INSERO and DTU Management



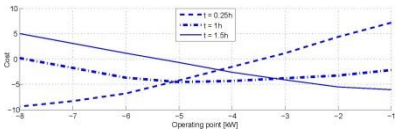
Distributed MPC for domestic loads

The goal of coordinating units is to constrain the aggregated consumption/production of a cluster (group of units) to a fixed value or to a specific schedule provided by a higher-level entity in the Smart Grid, such as an aggregator or the DSO (service is called “PowerMax”)

This coordination scheme is also suitable for other types of unit and allows units to join and leave the cluster dynamically.



RT-DPC System setup



FlexHouse (electric space heating)

EV - eBox (Vehicle 2 Grid)

PV 10kW installation

Custom interface

RA

RA

RA

Resource agent

ICF Pref

Cluster agent

Cluster agent

Cluster agent

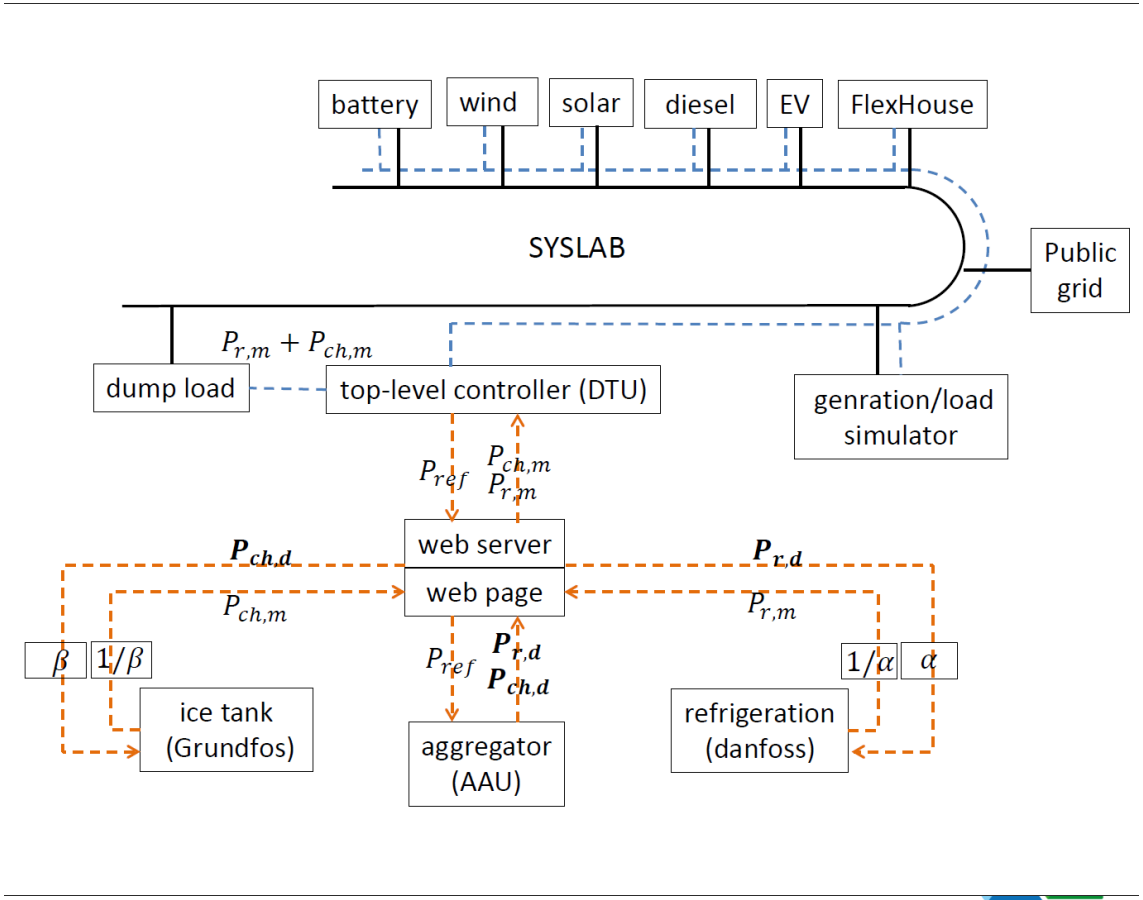
ICF Pref

Grid agent

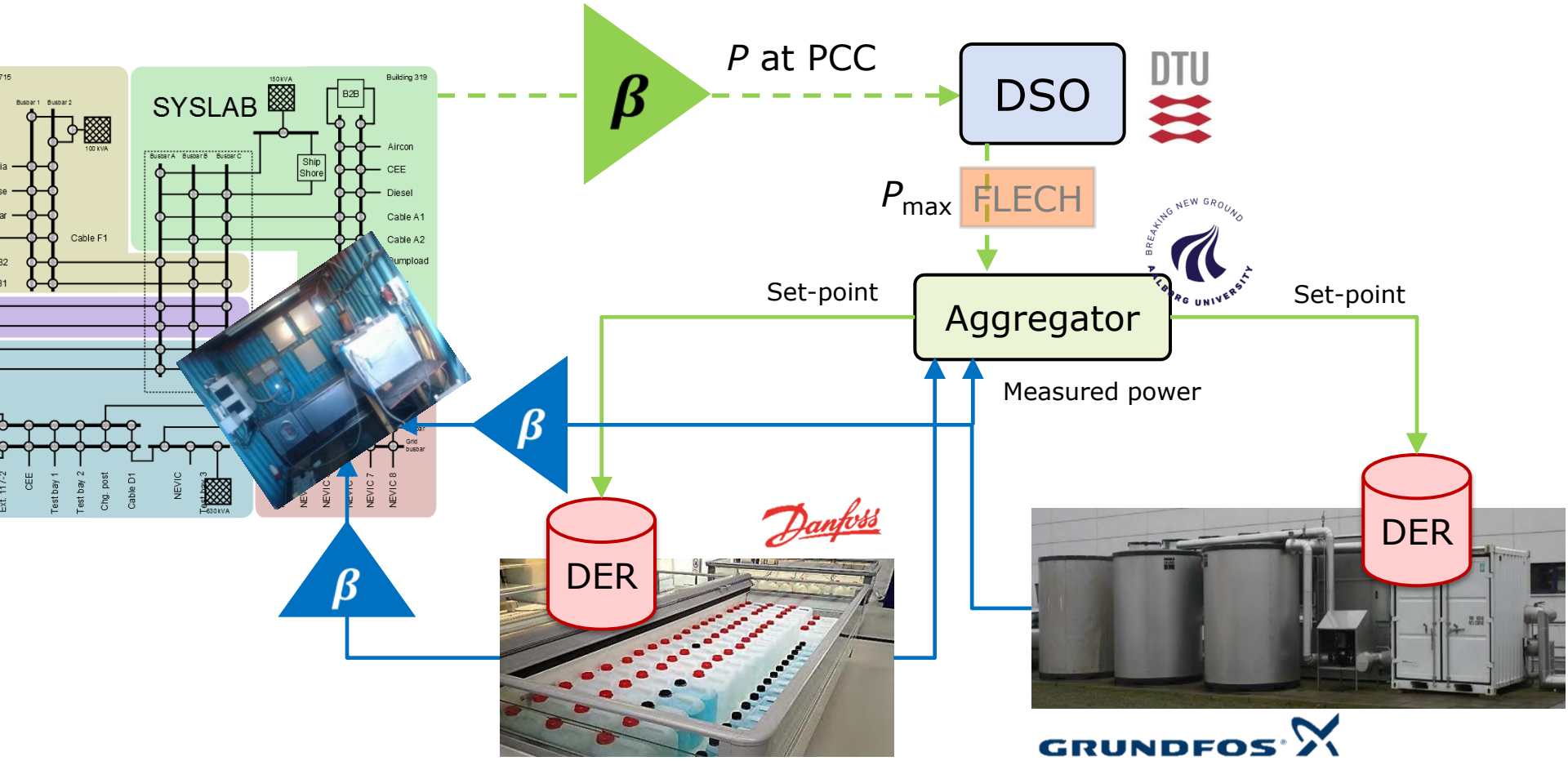
Standard interface

Demand response from industrial loads

- Optimizing Aggregator developed that takes differences of time constants into consideration
- Experiment that uses real hardware in the @Danfoss and @Grundfos and mirrors that load into SYSLAB
- The response from SYSLAB is communicated to Aggregator to enable it to re-optimize

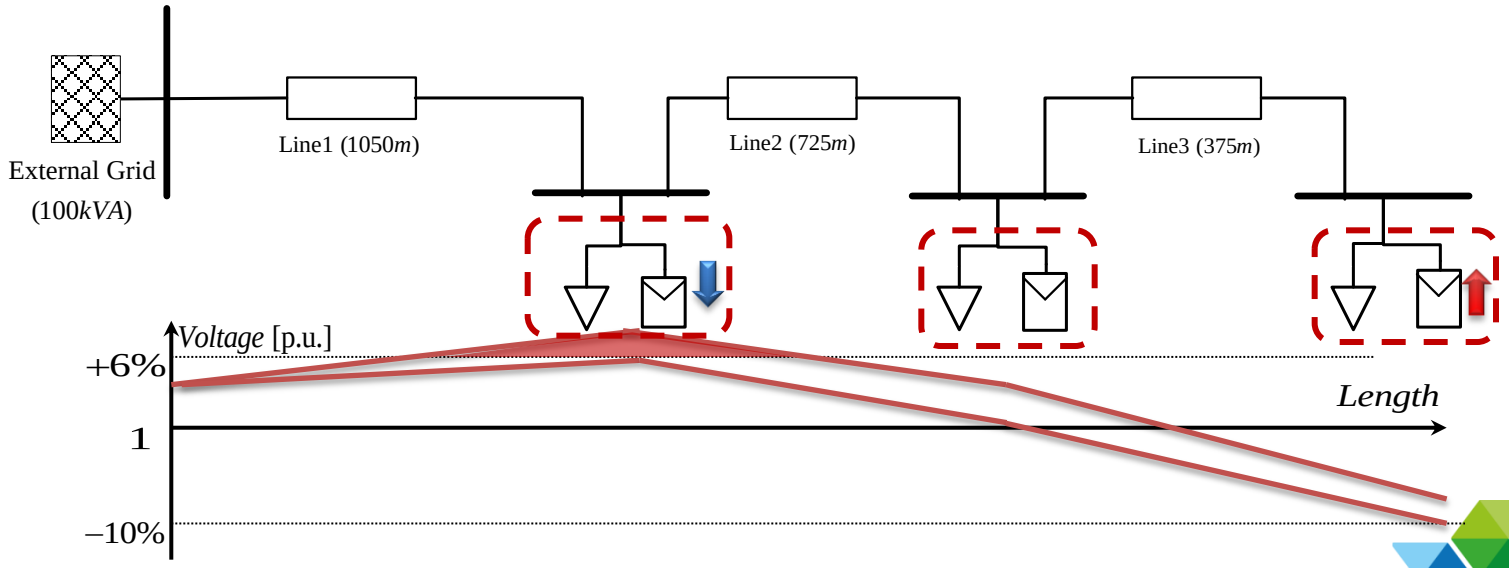


System setup



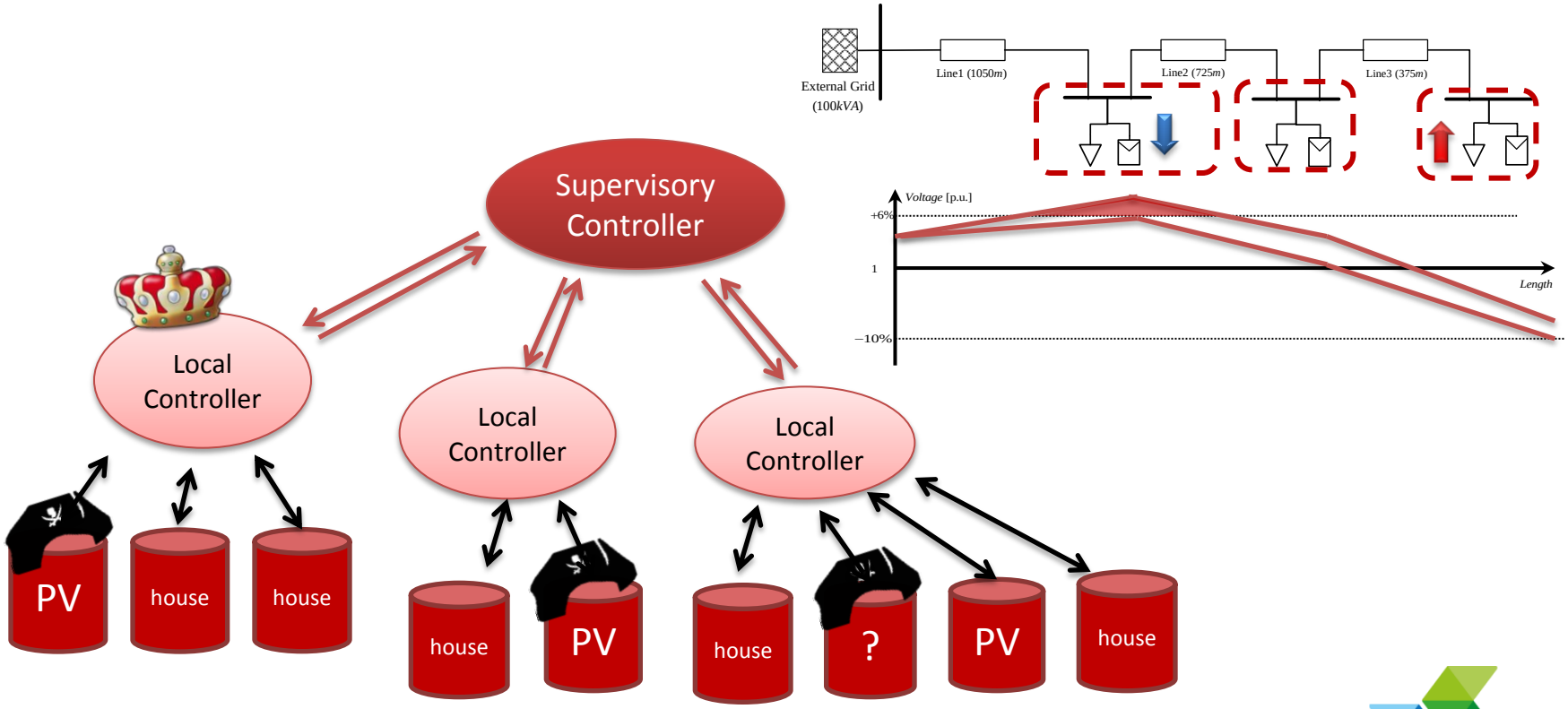
Voltage Controller (1)

- Background: An increasing fraction of PV in the grid + controllable load in resident house → Fluctuations of voltage in LV network (EN50160: +/- 10% in 10 minutes average rms)
- Problem formulation: Regulating active power and reactive power of available components to smooth the voltage profile along the feeder, by minimizing the overall cost of services and power loss.
- Experiment setup: Fixed topology of a radial feeder (SYSLAB), contracted services with PVs and residential loads (10 heaters per house) of certain cost.



Voltage Controller (2)

- Experiment setup: Fixed topology of a radial feeder (SYSLAB), contracted services with PVs and residential loads (10 heaters per house) of certain cost.
- Aggregation: flexible active power and reactive power
- Goal: voltage within the limit band & efficient power delivery

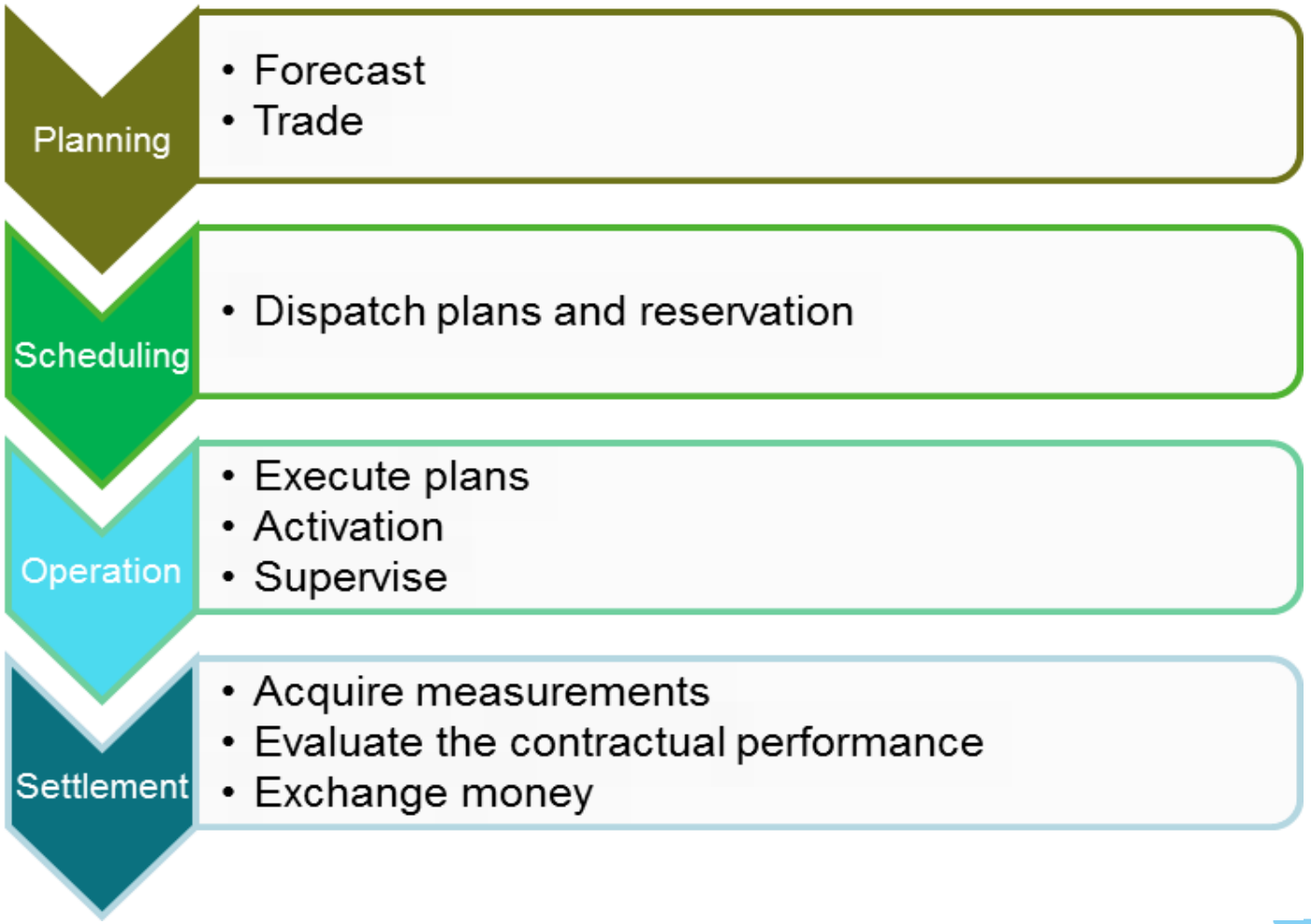


DSO services definitions

STRATEGIC PLATFORM FOR INNOVATION AND
RESEARCH IN INTELLIGENT POWER [IPOWER]

DEVELOPMENT OF A DSO-MARKET ON FLEXIBILITY SERVICES

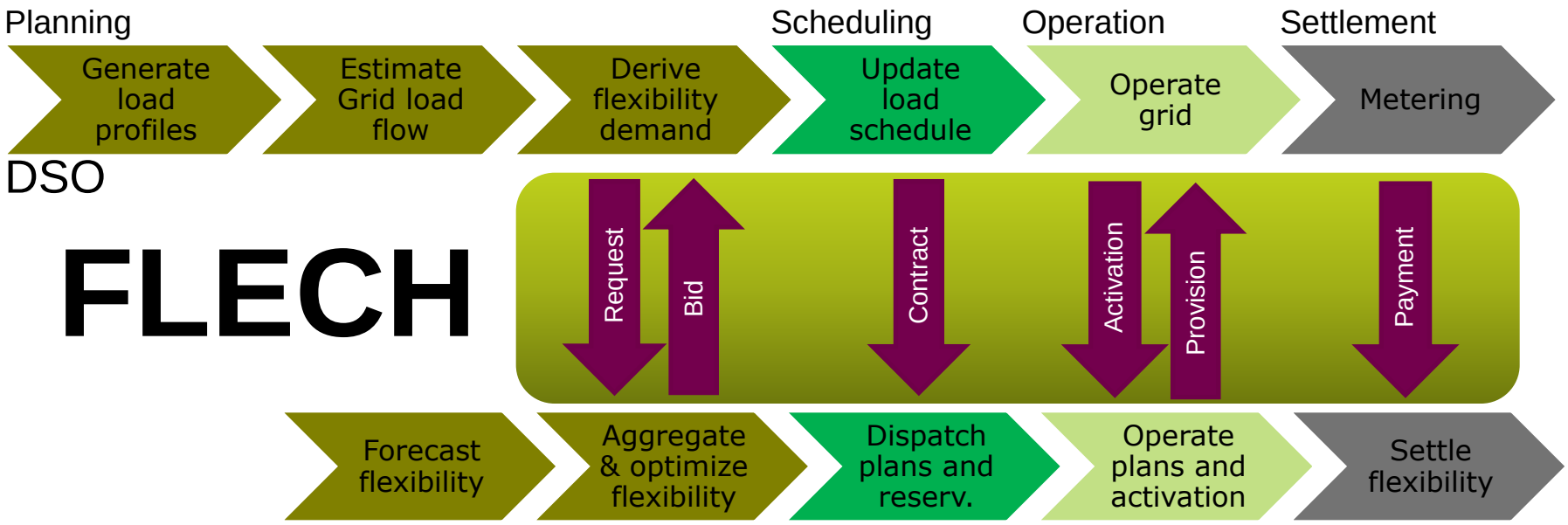
FLECH concept
Traditional decomposition



FLECH concept

Interaction between DSO and Aggregators

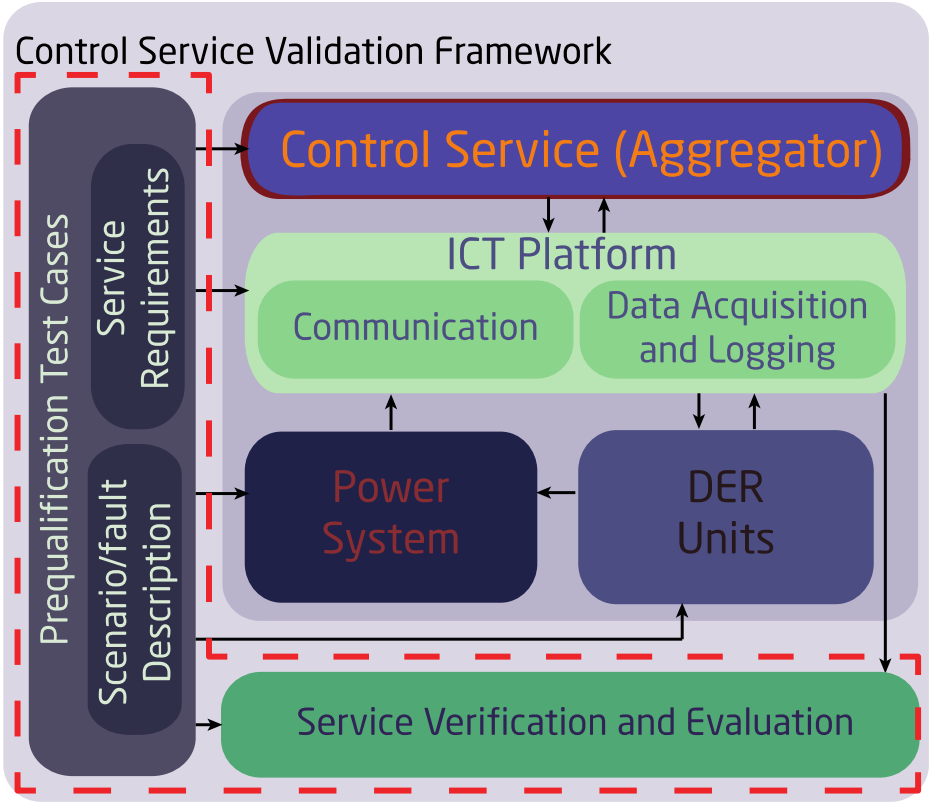
DSO Services:
- Load Management
- Voltage Management



Validation of control services

- **Main question:**
- How do we ensure the reliability of services provided by Control Services (e.g. Demand Response)?

- Can formalized methods for validation be applied?



- Published paper: "Performance Assessment of Aggregation Control Services for Demand Response" @ IEEE PES ISGT 2014
- Technical report (to be published online soon): "FLECH PowerMax Service Requirement Specification".

Conclusions I

- Future power systems with RE and increased electrification will lead to operational challenges at the system level as well as at the local grid level of the power system
- There are resources in the distribution grid that can contribute to the solution of these challenges
- iPower is a Danish innovation and research project that is developing demand response solutions that be applied to solve the future power system challenges
- The solutions will have to involve the users/customers/owners of equipment to allow the flexibility to be available and technological solutions to enable the integration into the operation of the power system

Conclusions II

- In iPower several solutions for control of residential demand response has been developed and tested
- The solutions include both solutions to local grid issues as well as system balancing
- A framework FLECH that can be used to provide a transparent interaction between DSO and Aggregators have been developed and tested
- It has been demonstrated how flexible units can provide well-defined services coordinated by an aggregator to a DSO
- There are ongoing testing of user interfaces for maximising the flexibility offered by the users

Next iPower events

- 3-4 November 2015
  - Event in Copenhagen
  - Day 1: Flexibility Economy – results of economic analysis incl. business cases for some of the commercial loads
  - Day 2: Avoiding bottlenecks in distribution grids using smart grid

- 11 May 2016
  - DTU Risø Campus
  - Final event
  - Presentation of main results and perspectives

Questions

Thank you

Henrik Bindner

Senior Scientist

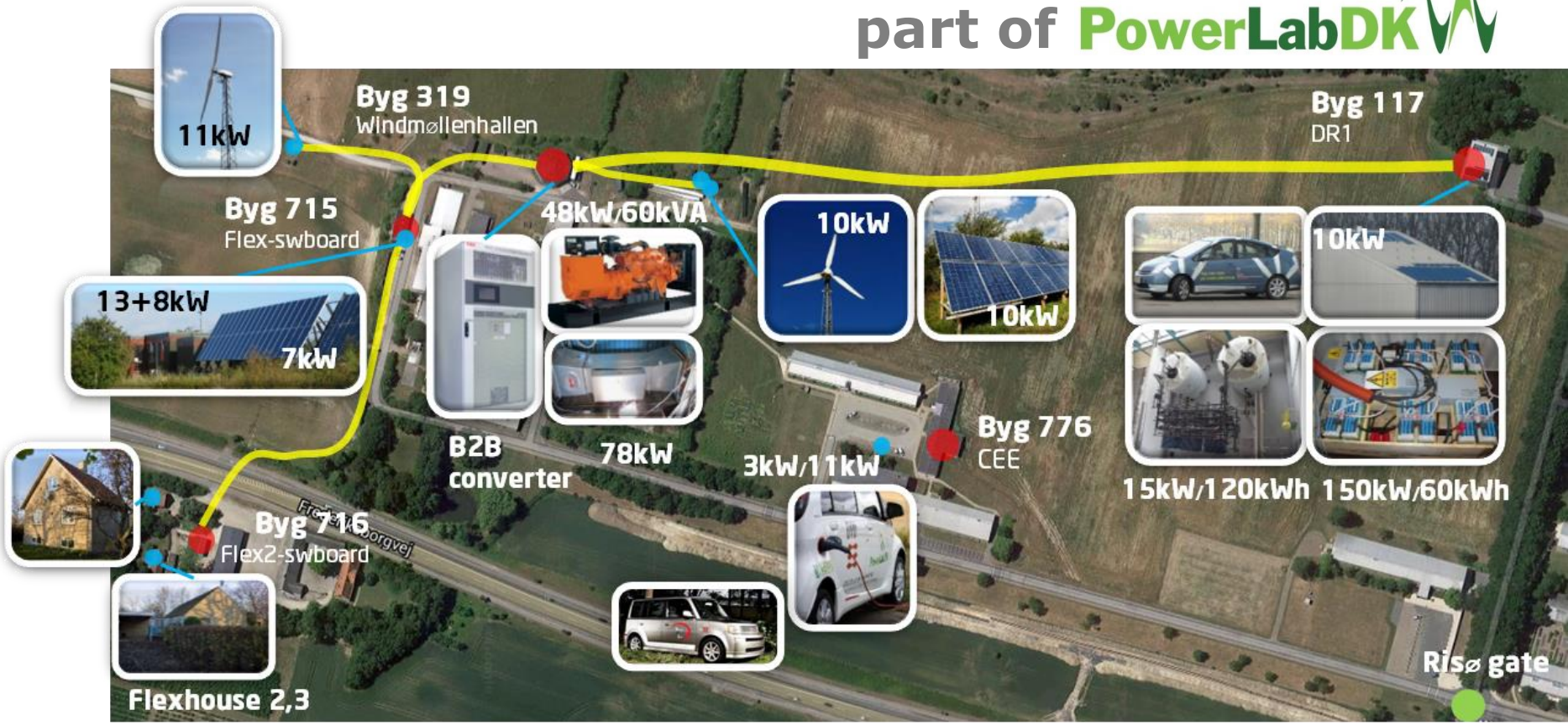
Energy Systems Operation and Management

Center for Electric Power and Energy

hwbi@elektro.dtu.dk

SYSLAB – Distributed Energy System Laboratory

part of PowerLabDK



- 3 additional load simulators (mobile and stationary)
- Capacitor bank
- Hydrogen-based CHP (to be installed)

iPower

SYSLAB / Hardware platform

•Every unit is supervised locally by its own controller “node”. Nodes contain a computer, measuring and network equipment, data storage, backup power and field buses “in a box”.

•Each node can communicate with all other nodes.

•The design does not enforce a central controller. The whole system can be run from anywhere.

•21 SYSLAB nodes +20 helper machines, total ~1000 source files

Aggregation concepts

- Several existing concepts for resource aggregation in power system control
- Microgrids
- Cells
- Virtual Power Plants (VPPs)