TASK 2.2
OPTIMIZATION
AND PLANNING

Flexibility Supporting Functionalities and Technical Solutions of LVDC Microgrids

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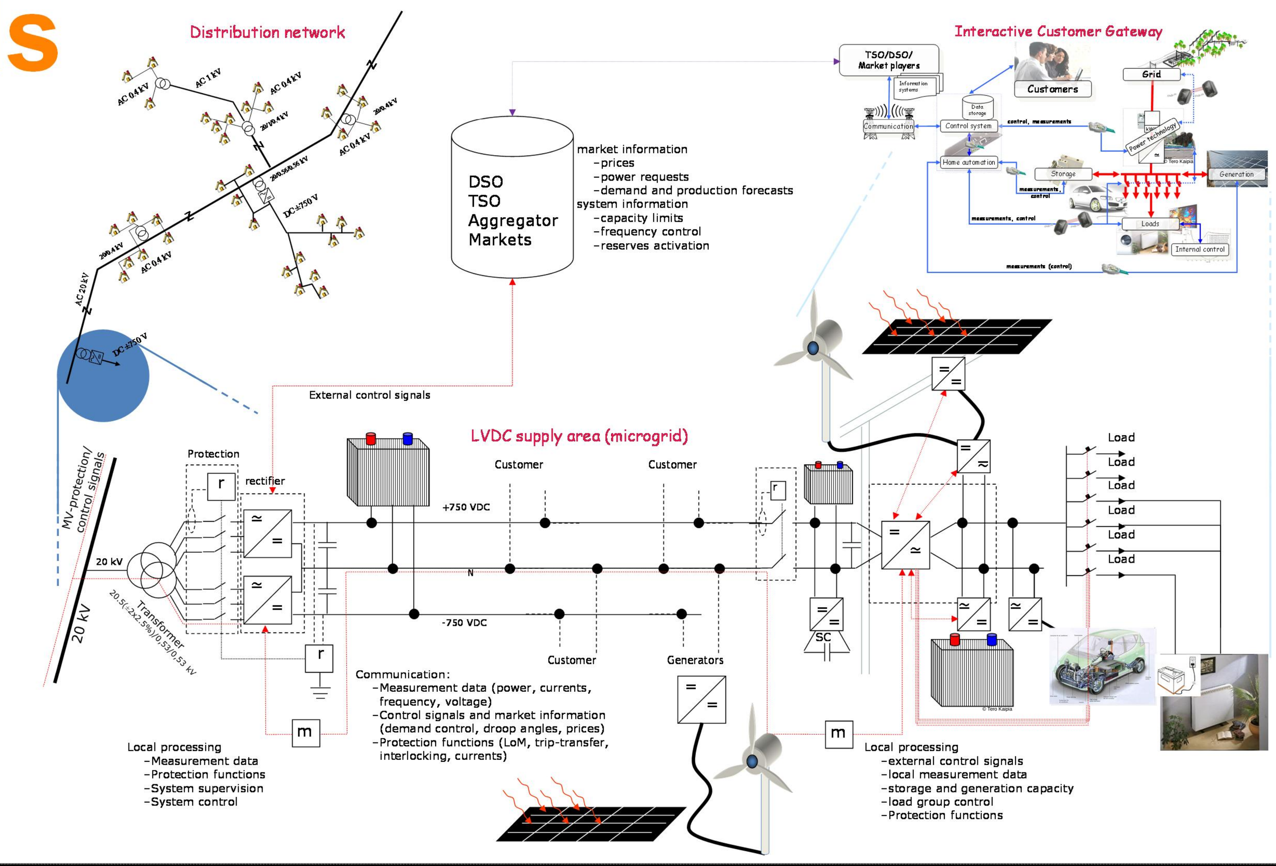
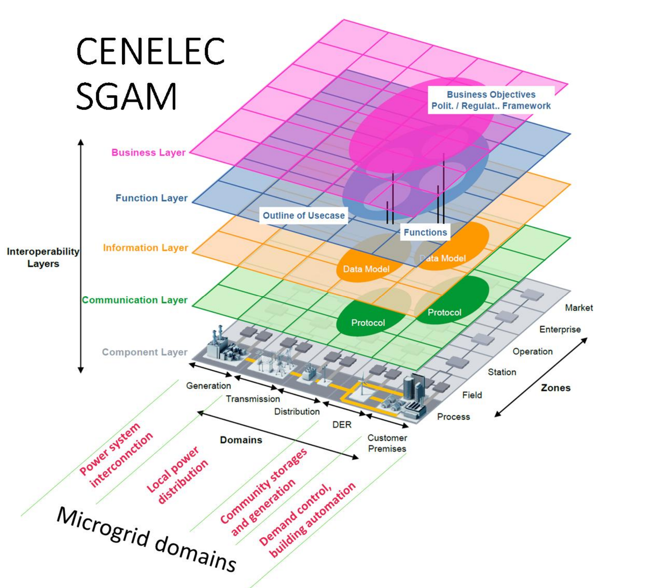
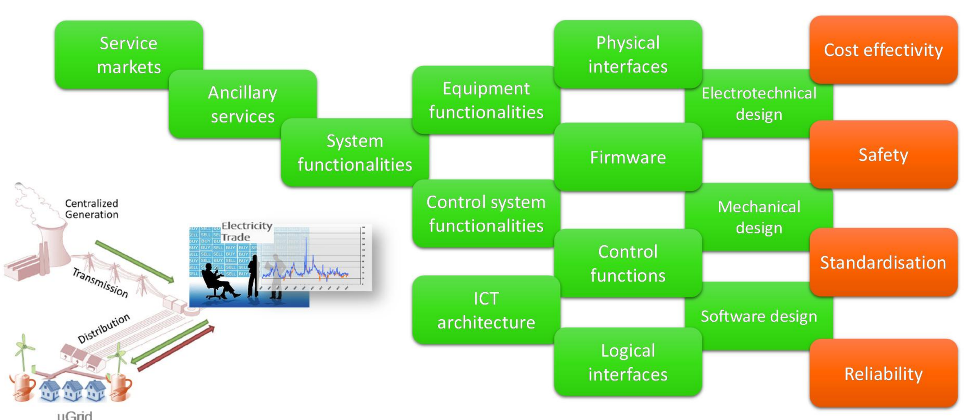


Tero Kaipia, Andrey Lana, Ville Tikka, Antti Pinomaa, Aleksi Mattsson, Janne Karppanen, Pasi Nuutinen, Pasi Peltoniemi, Jukka Lassila, Pertti Silventoinen, Jarmo Partanen

Overall objectives

- ✓ Investigate use of LVDC technology and its intelligent functionalities as a platform for flexibility services
- ✓ Determine flexibility services oriented functional and operational requirements for converters and embedded ICT of LVDC microgrids
- ✓ Demonstrate implementation and operation of pivotal flexibility supporting functionalities by using research platforms
- ✓ Develop and verify technical solutions enabling feasible realization of LVDC microgrids and exploitation of their flexible resources
- ✓ Study role of LVDC-enabled flexibility supporting functionalities on ancillary services markets





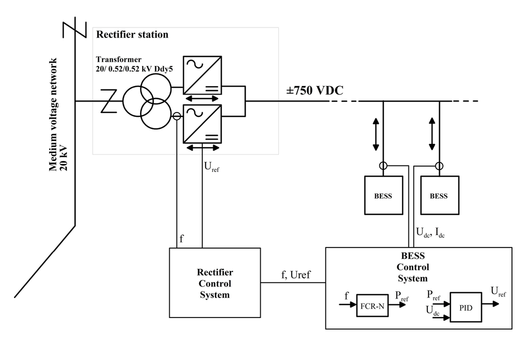
Flexibility services in systems engineering of LVDC microgrids

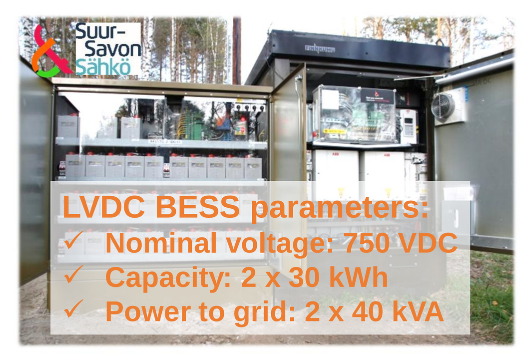
Research questions by layers

- ✓ What business models enable effective deployment of µGrid resources?
- ✓ What kind of µGrid resources based ancillary services?
- ✓ What kind of management architectures are needed to support deployment µGrid resources?
- ✓ What are the main functionalities that a µGrid management system is required to perform?
- ✓ What are the functional requirements for the technical solutions and their feasible implementations

Demonstration – LVDC connected BESS as frequency controlled resource

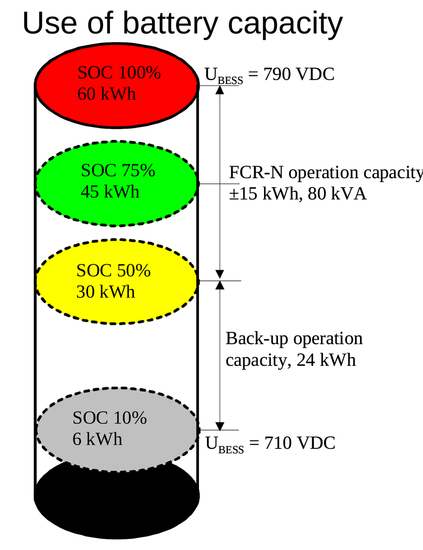
Demonstration of the implementation and application of the Frequency Containment Reserve for Normal operation (FCR-N) functionality in control system of the centralized, directly connected battery energy storage system (BESS) in the LVDC pilot network of Suur-Savon Sähkö Oy.





Main diagram of the system

Use of battery capacity



FINGRID

FCR-N min. requirements:
- ✓ Minimum size 0.1 MW
- ✓ Full activation in 3 min
- ✓ Reaction in 2 s
- ✓ Dead band max. ±0,05 Hz
- ✓ Droop max. 6 %

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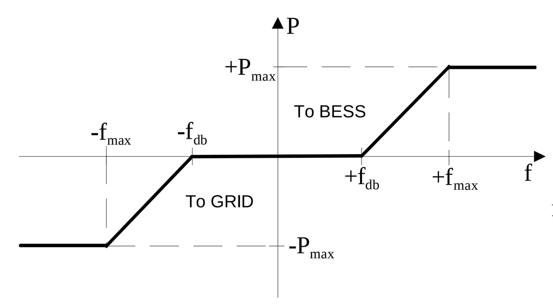
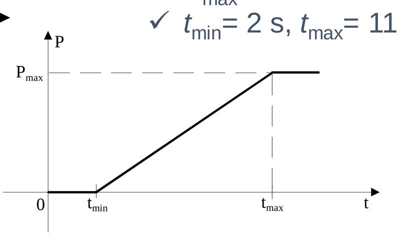


Graphical representation of FCR-N control – the droop curve.

FCR-N demonstration:
- ✓ f_{db}= 0.05 Hz, f_{max}= 0.1 Hz
- ✓ P_{max} = 10 kW
- ✓ t_{min}= 2 s, t_{max}= 11 s

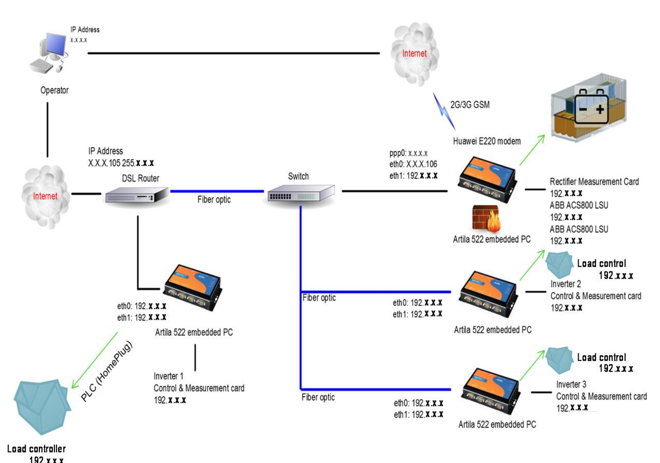


Restrictions on the rate of change of power

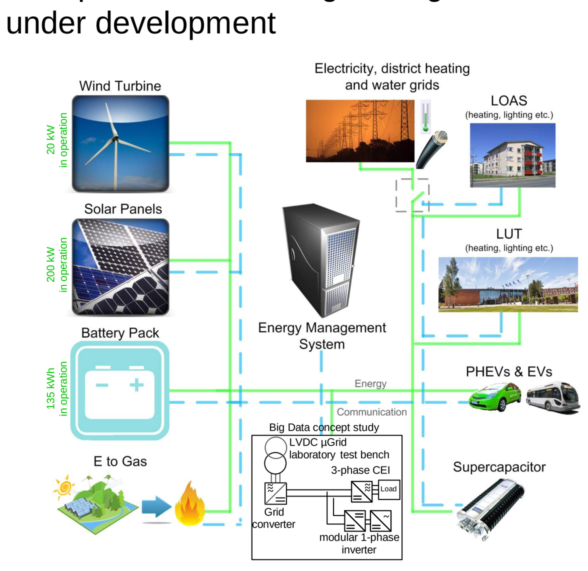
Enabling technology
ICT System

Role of ICT in LVDC microgrids development
- ✓ Enabler for microgrid functionalities and platform for applications
- ✓ Between backhaul networks and through distribution grid to customers
- ✓ Supervision & control grids, customer loads, energy storages, protection functions, etc.

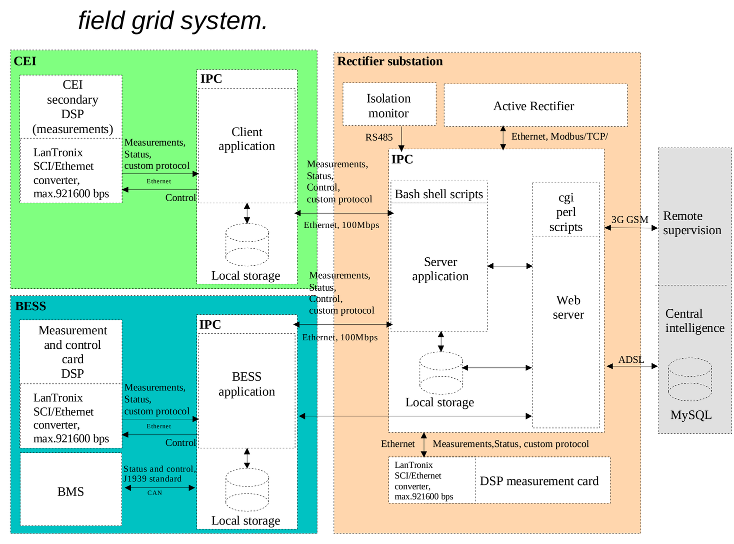
LUT Green Campus
- ✓ New platform for testing microgrid functionalities under development



Communication networks and connections of the LVDC field grid system.

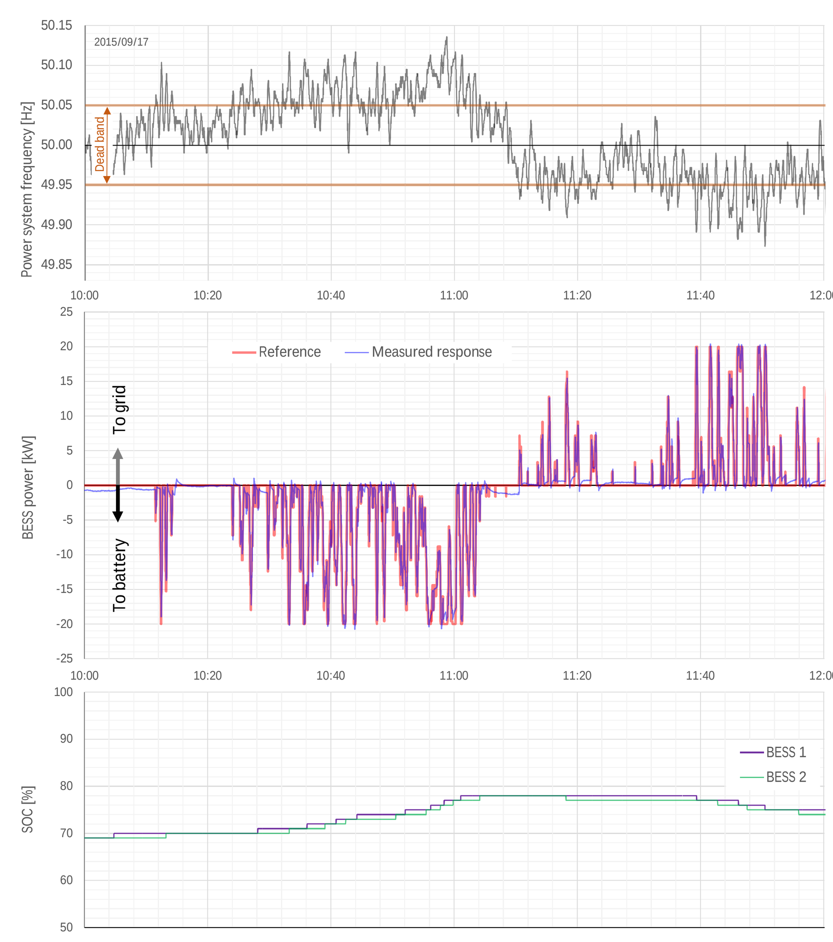


LVDC µGrid integration into LUT Green Campus environment

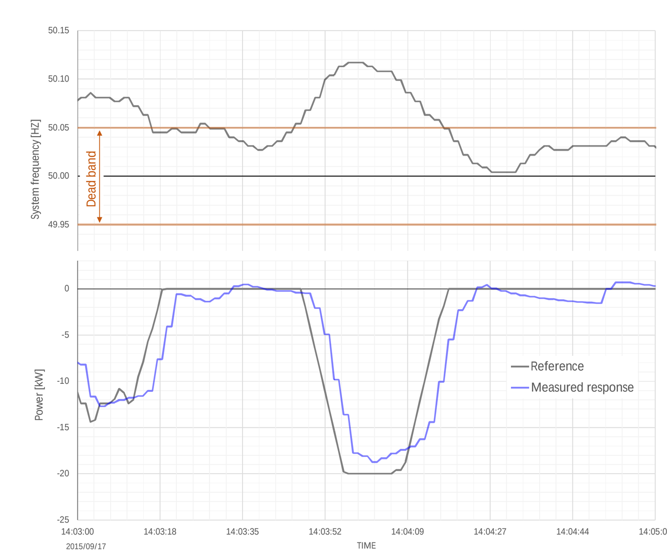


Architecture of the LVDC ICT system presenting the supervision and control solution.

FCR-N control in operation



Results from a test run. Measured frequency, total BESS power and SOC of the battery units.

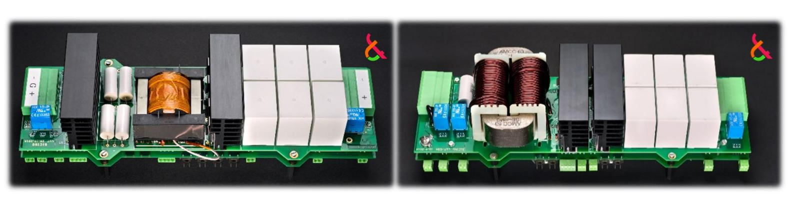


BESS response to frequency changes

Challenges due to existing equipment
- ✓ Resolution of the DC voltage control of the commercial grid-tie converter insufficient
- ✓ Too slow M2M data transfer rates

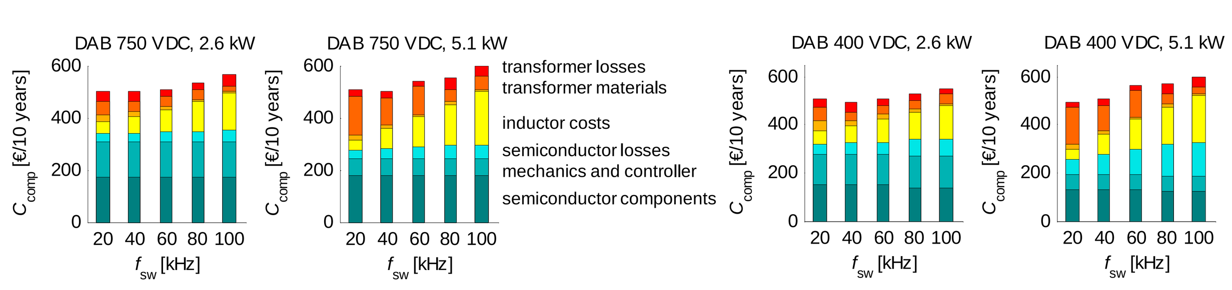
Key research questions
- ✓ Multi-objective optimisation of the usage of the battery capacity
- ✓ Real-time adaptive control of the BESS, and short-term predictive SOC optimisation
- ✓ Optimal sizing of BESS for power system interconnected LVDC microgrids
- ✓ Interactions between different controls and system specific (BESS in LVDC network) constrains

Converter design

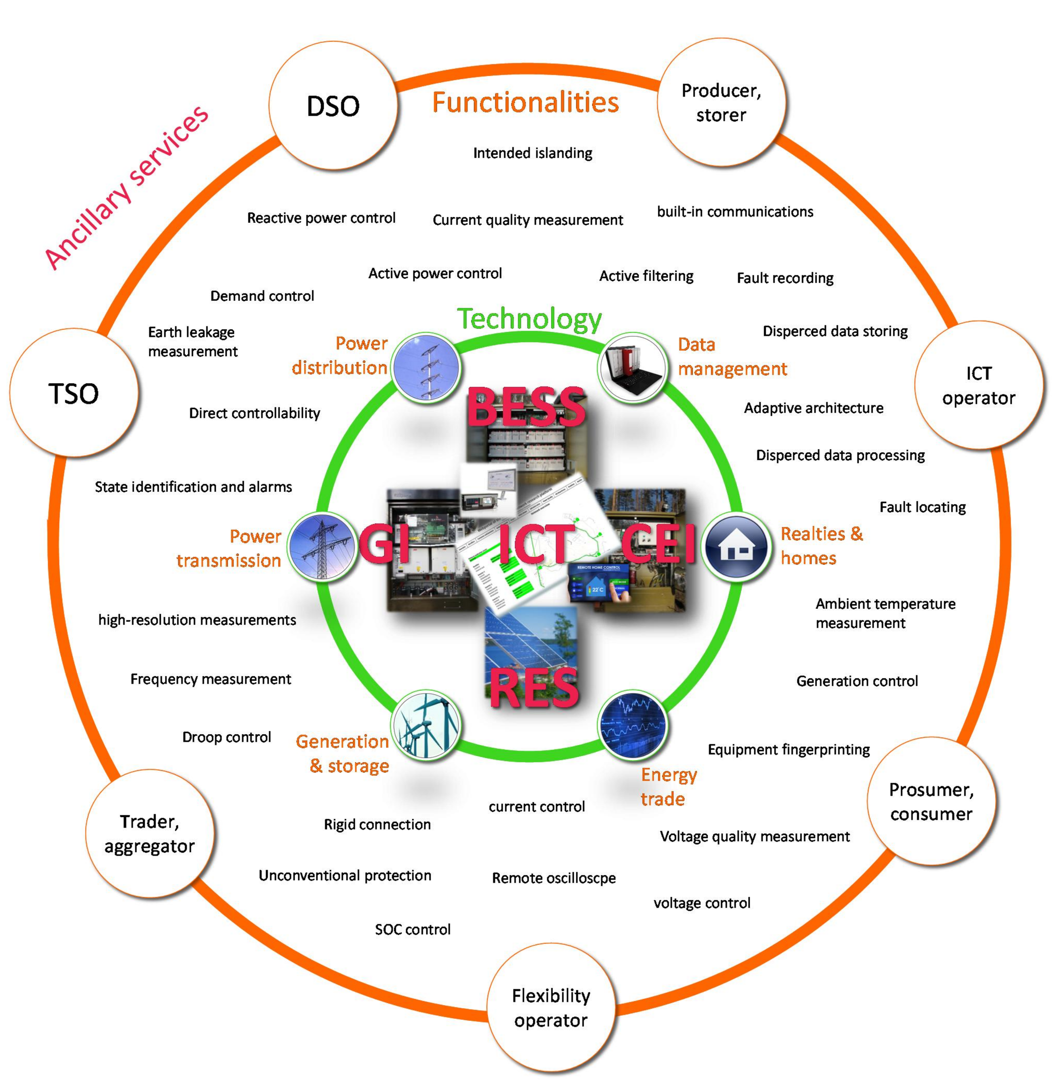


Prototype of DC/DC converter module with galvanic separation and DC/AC converter module for customer-end inversion (3 kW)

Research topics
- ✓ State-of-the-Art technologies for improving energy and cost efficiency
- ✓ Development of methodos for optimal design
- ✓ Life-cycle cost analysis of versatile converter topologies for different purposes



Impact of switching frequency, rated power and output voltage on life-cycle costs of dual active bridge (DAB) DC/DC converter module with galvanic separation. *(A.Mattsson et Al., Evaluation of Isolated Converter Topologies for Low Voltage DC Distribution, Paper accepted for publication in IECON 2015)*



Functionalities of an LVDC microgrid – Basis for providing ancillary services for different market players

Results so far…

- Two conference articles published, one accepted for publication
- Writing of two articles in progress, one more planned
- One dissertation in pre-examination
- First demonstration realised, research platforms under development
- All deliverables defined and scheduled

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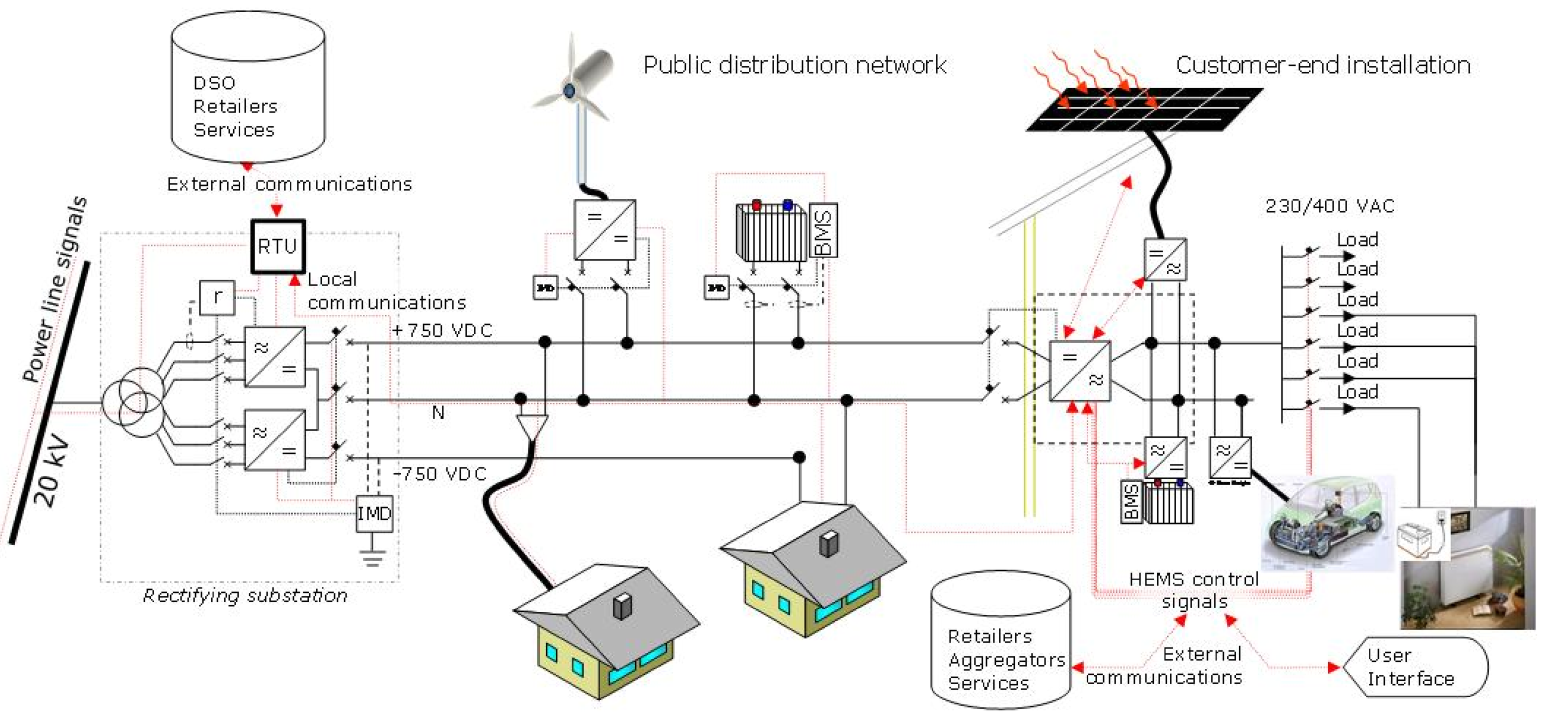
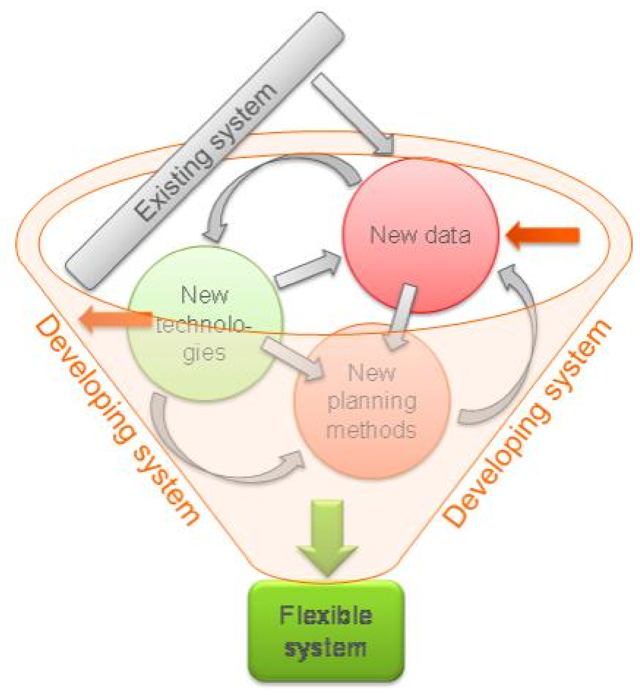


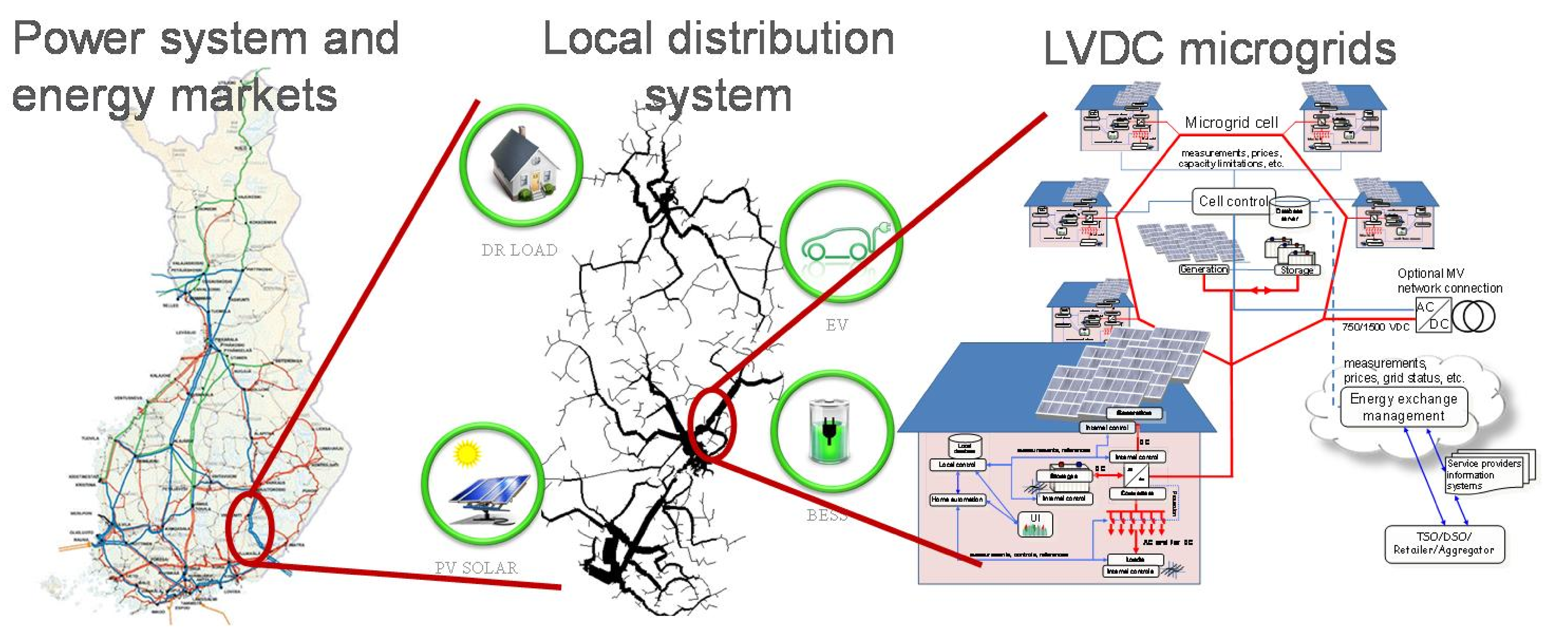


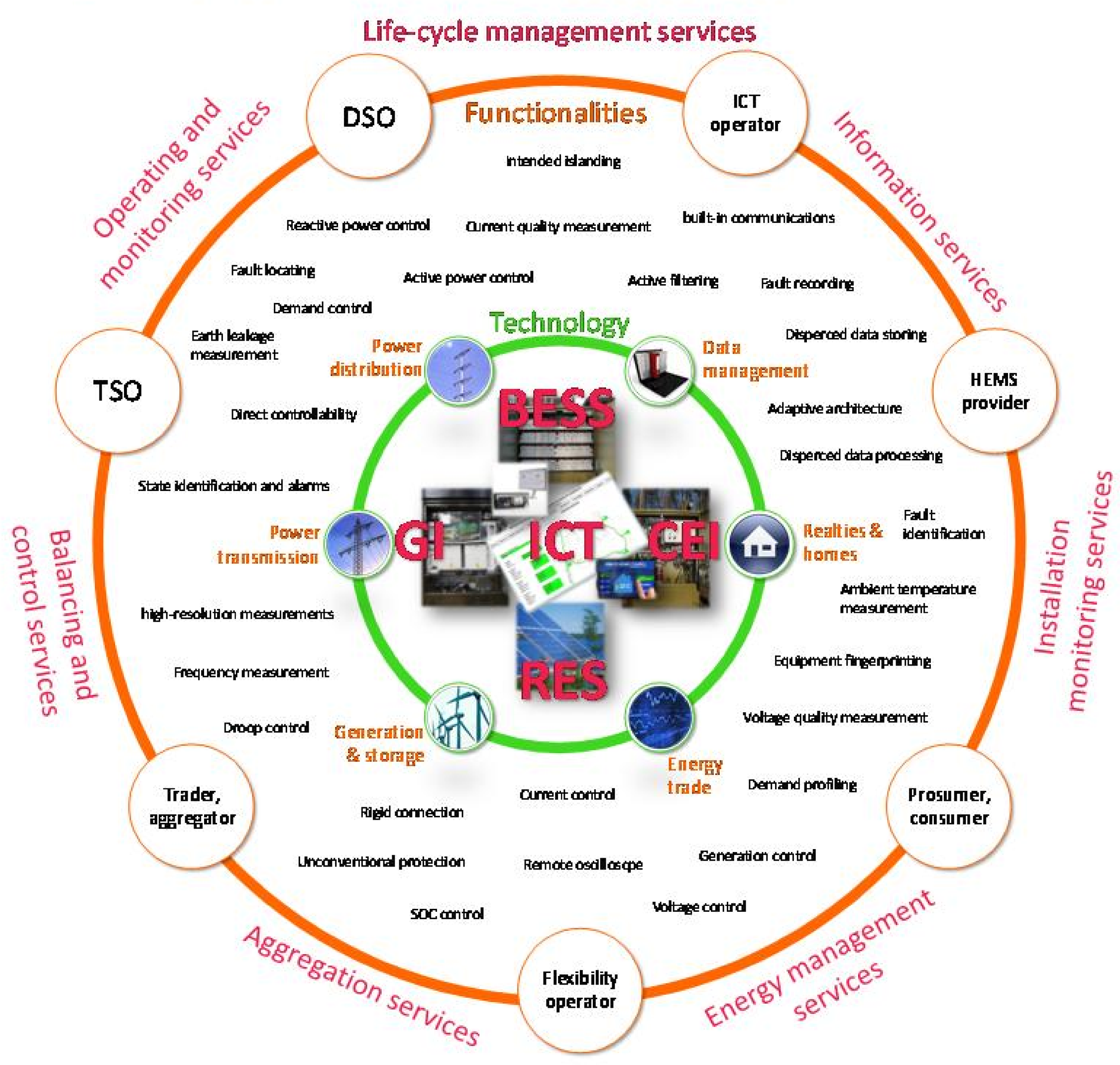
TASK 2.2 OPTIMIZATION AND PLANNING

LVDC in Providing Ancillary Services for Electricity Markets and Power System Management

LUT LVDC Research Team
Tero Kaipia

The control abilities of the active converters and the embedded ICT system of the LVDC distribution system enable exploitation of the local flexible resources to offer ancillary services for all the market players





Main outcomes

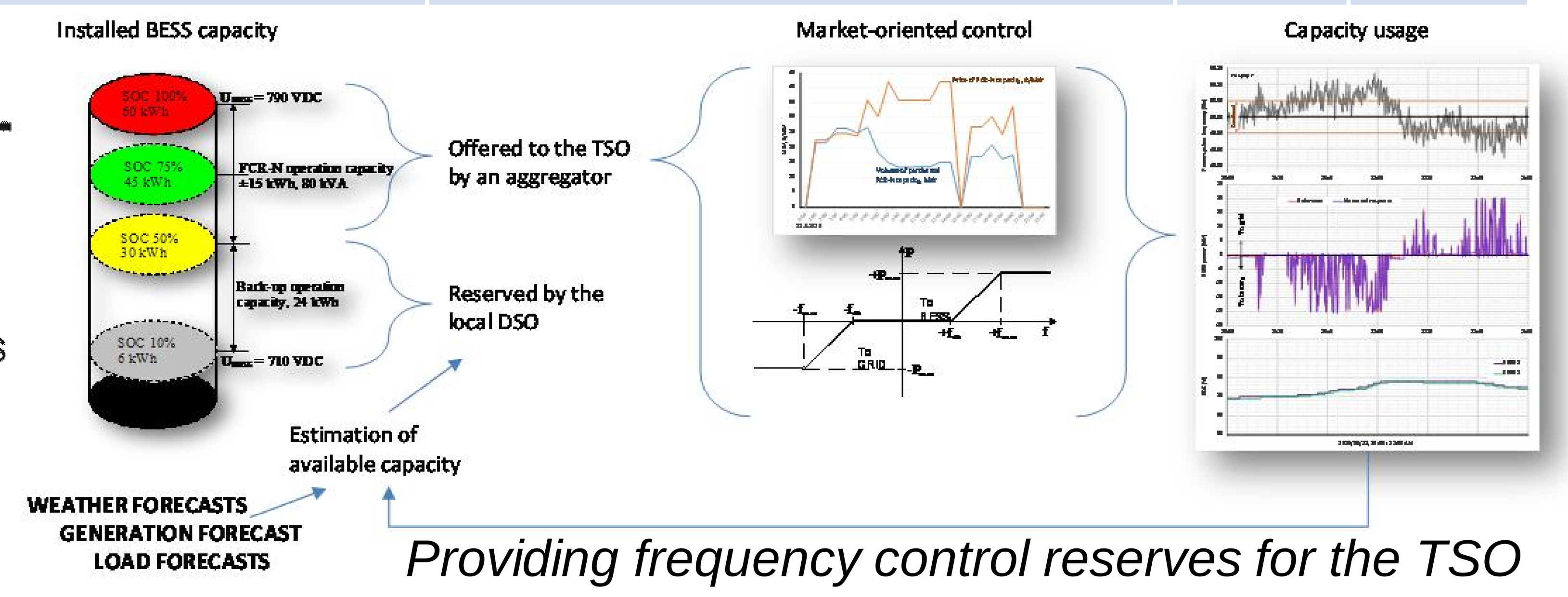
- Redefinition of the ancillary services concept in electricity markets
- Use-case definitions for several LVDC enabled ancillary services
- Development of the LVDC system architecture from the ancillary services perspective
- Rough estimation of the power-system-wide significance of LVDC as an enabler of flexibility

Further research topics

- Comparison of the costs of flexibility between traditional AC and hybrid AC-DC networks
- Determination of the value of different services for the market players on microgrid internal and external markets
- Development of the electricity market models to enable efficient exploitation of microgrids and included resources
- Optimisation of the allocation of the resources between markets
- Development of the market-oriented control algorithms for LVDC microgrids and for hybrid AC-DC microgrids

Example of ancillary services available for DSOs

Ancillary services for DSO	Used functionalities	Inherent DC functionality	
		Yes	No
Reactive power balance management	– Rectifier reactive power control	✓	
Voltage control	– Rectifier reactive power control – DC-connected storage control – Demand control	✓ ✓ ICT	 ✓
Power flow management	– DC-connected storage control – Demand control – Rectifier reactive power control	✓ ICT ✓	 ✓
Equipment condition management	– Converter condition monitoring – Earth leakage monitoring – Protection device monitoring – LV cable condition monitoring – MV cable condition monitoring	✓ ✓ ✓ (✓) ICT	 ✓
Interruption / fault management	– Fault locating in LV network – Fault locating in MV network – Automatic LV reconfiguration – Communications gateway for automatic MV reconfiguration – Island operation	✓ ICT ✓ ✓ ICT	 ✓ ✓
…	…		



Providing frequency control reserves for the TSO

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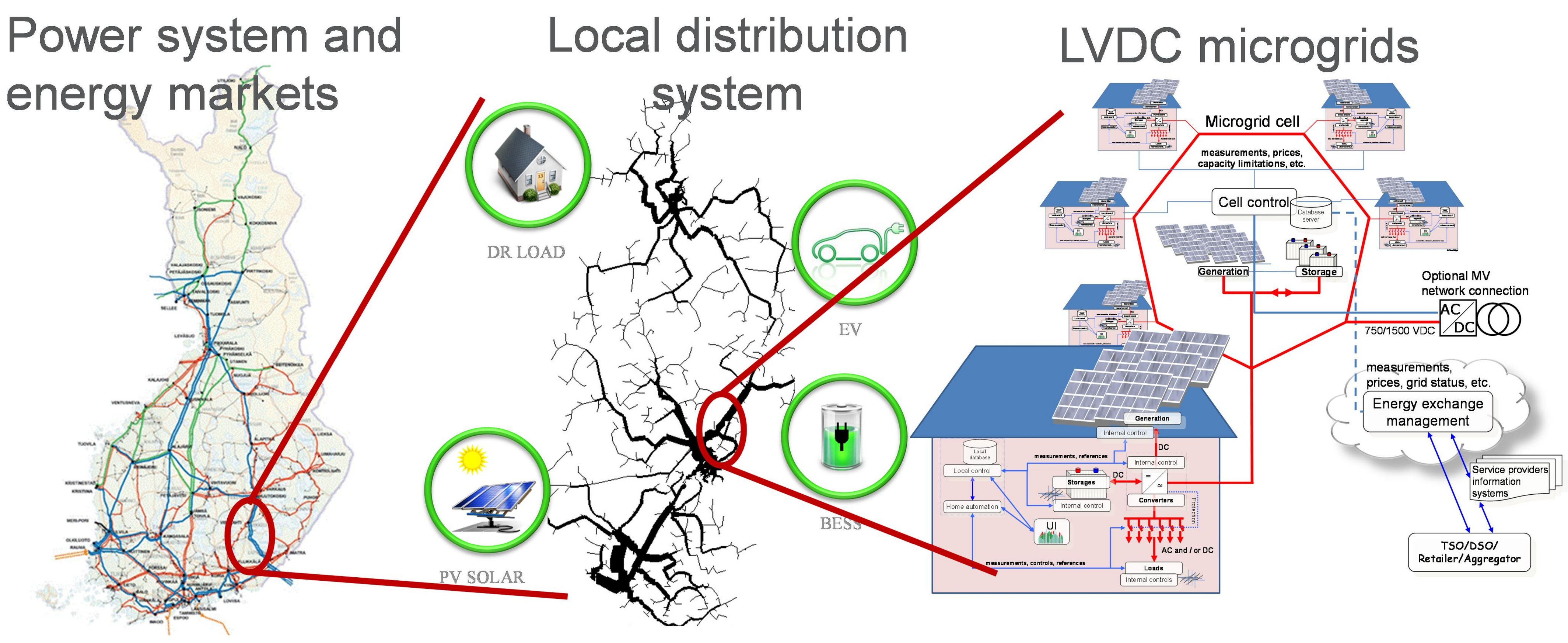
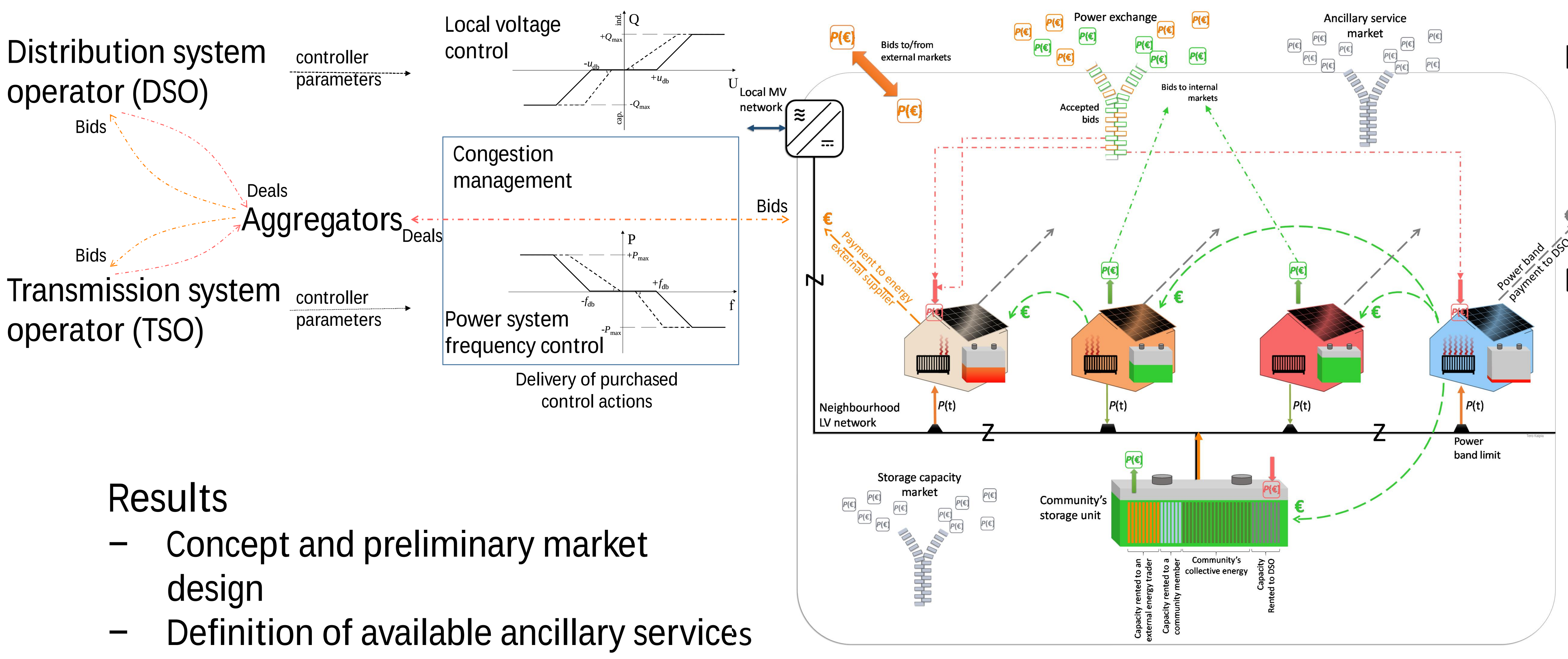


Microgrid as an active enabler for energy system flexibility

Tero Kaipia
Lappeenranta University of Technology

Growing role of weather dependent renewable generation and the pursuit of weather independent power delivery are leading to increasing need of regulating capacity and network investments. Major part of the renewable generation capacity will be connected via building installations into the low-voltage networks next to the loads and consumer-end energy storages. At the same time the distribution companies are boosting the performance of the networks by increasing automation and considering implementation of new network technologies, such as, the low-voltage DC distribution. Consequently, the basic energy resources and infrastructure for realising microgrids are becoming inherently available, and thus, they are one of the key building blocks of the flexible and resilient energy system.



Internal power exchange

- Energy cost minimisation
- Efficient use of local renewable resources
- Preparation to emergencies
- Internal power balancing

External power exchange

- Energy cost minimisation
- Maximisation of profit from ancillary services
- Need to cover microgrid power/energy surplus/deficit

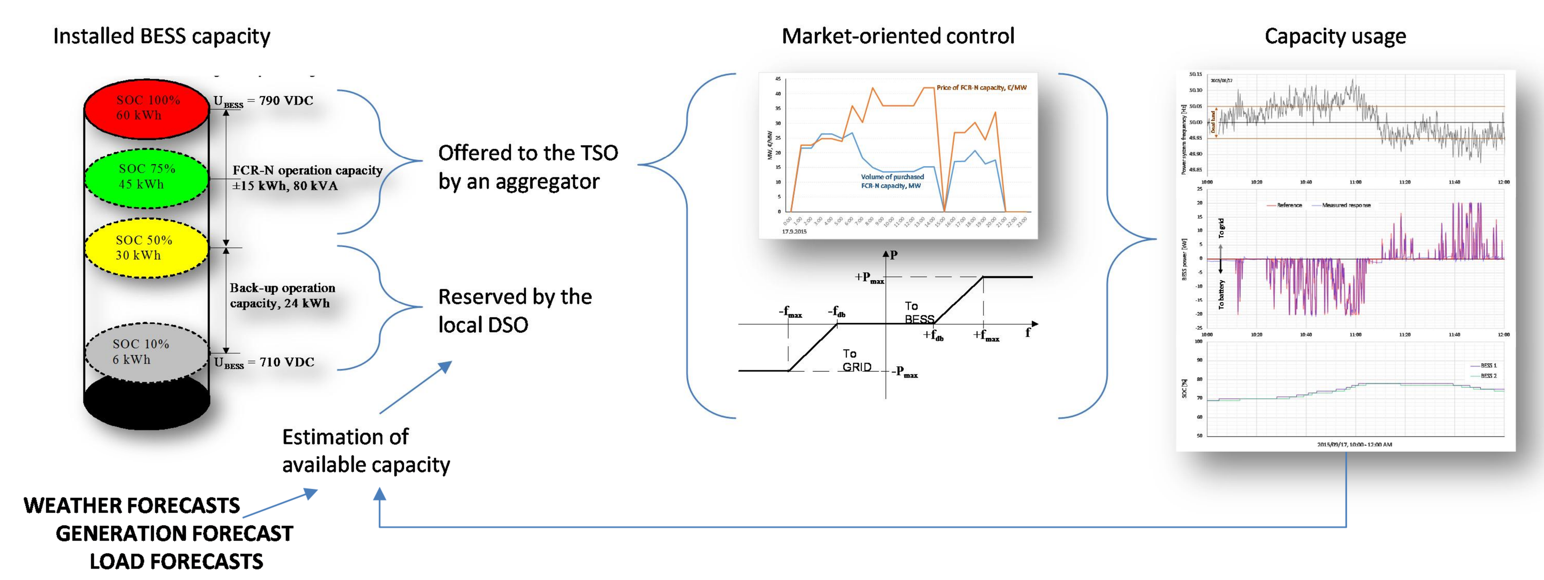
Scalable architecture

- Household scale
- Block scale
- Neighbourhood scale

A concept of μGrid having automated internal power exchange markets that are interfaced with respective external markets

Results

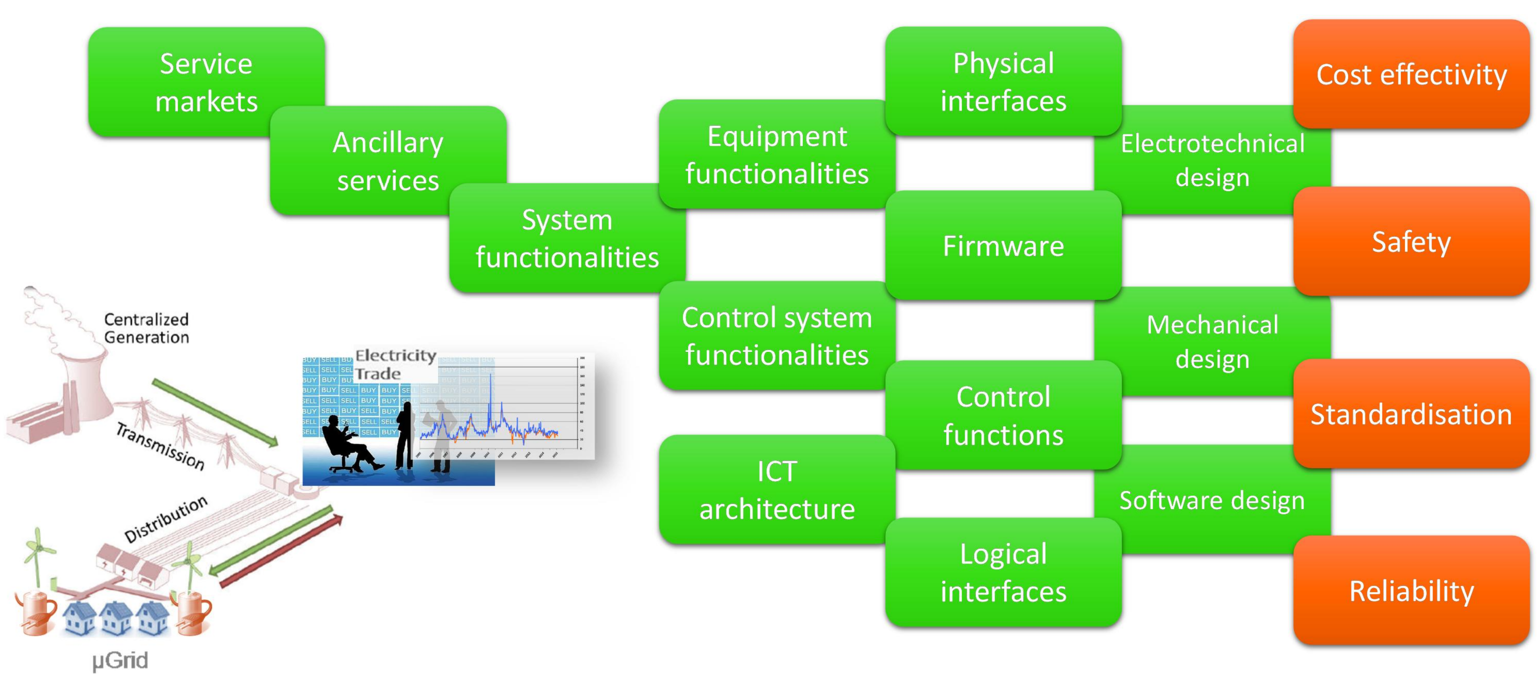
- Concept and preliminary market design
- Definition of available ancillary services based on inherent technical functionalities
- Demonstration of technical key functionalities
  - Independent off-grid operation
  - use of community battery as resource for FCR-N
  - MV network reactive power compensation



Demonstration of using community BESS as resource for power system frequency control (FCR-N)

Further research topics

- Electricity market models
  - Internal power exchange markets
  - Integration with external markets
  - Grid operating business
- Development of the market-oriented control algorithms
  - Allocation of the resources between markets
  - Optimal of microgrid operation
  - Transmission and distribution system operation
- Value of flexibility provided through microgrids
  - Consumer perspective
  - Business perspective
  - Socio-economic perspective
- Knowledge and technology to enable the change
  - Simulation models for studying market and grid impacts
  - Methods for market forecasting
  - Methods for system and network planning
  - Interaction between forms of energy: heat-electricity-cooling



Flexibility services in microgrid systems engineering

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FLEXe Result Seminar 31.10.2016

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Microgrid:
A small-scale power system that can operate independently or in conjunction with the interconnected main grid