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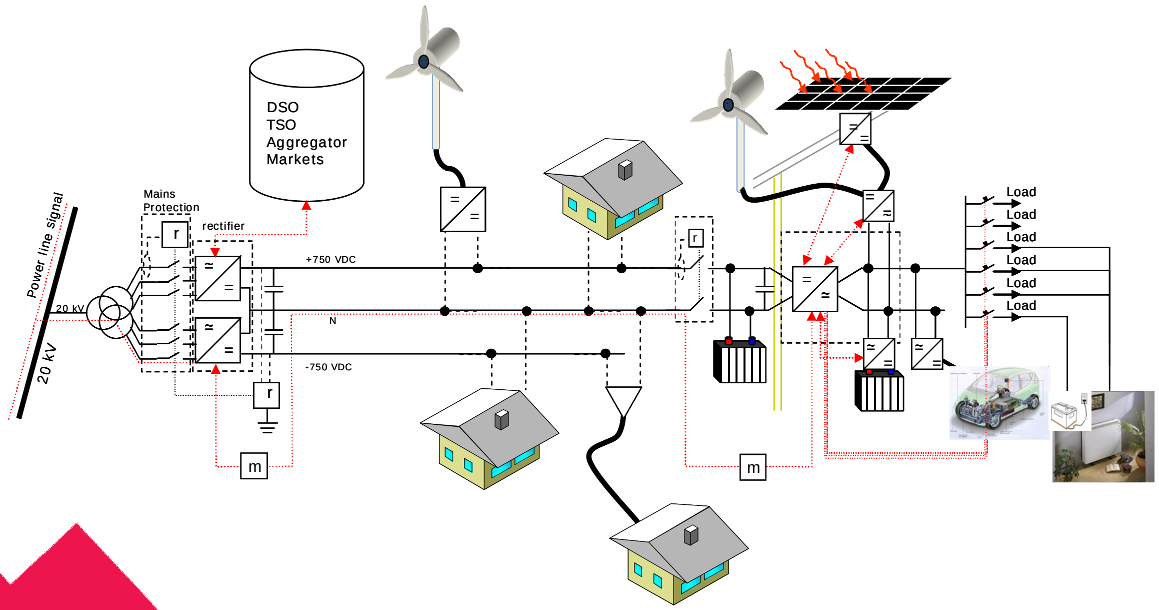
Concepts for LVDC microgrid



Henri Makkonen
Tero Kaipia

INCA in LVDC
- Concepts for LV microgrid

- LVDC microgrid concept leans on the technology and functional concepts of LVDC power distribution and Interactive customer gateway (INCA)
  - LVDC provides physical network and opportunity to actively control both the public network and end-customers installations
  - INCA provides the human machine interface, communications with external information systems of service proders and intelligent decision making algorithms for controlling the system locally
- LVDC system concept
  - ICT network components
    - PCs with PLC or fiber connects equipment to each other
    - Optical fiber/ADSL/@450 connects LVDC to backhaul network (IEC-101 SCADA)
    - Customer interface (MHI)
  - Rectifier
    - voltage control and measurements
  - Customer inverter
    - voltage and load control, PQ-control and measurements
- INCA concept
  - Decision making and control algorithms for local system handling
  - Interfaces to external information systems for remote system handling and data exhcange
  - Internal information network for local controls and MHI

Objectives and requirements

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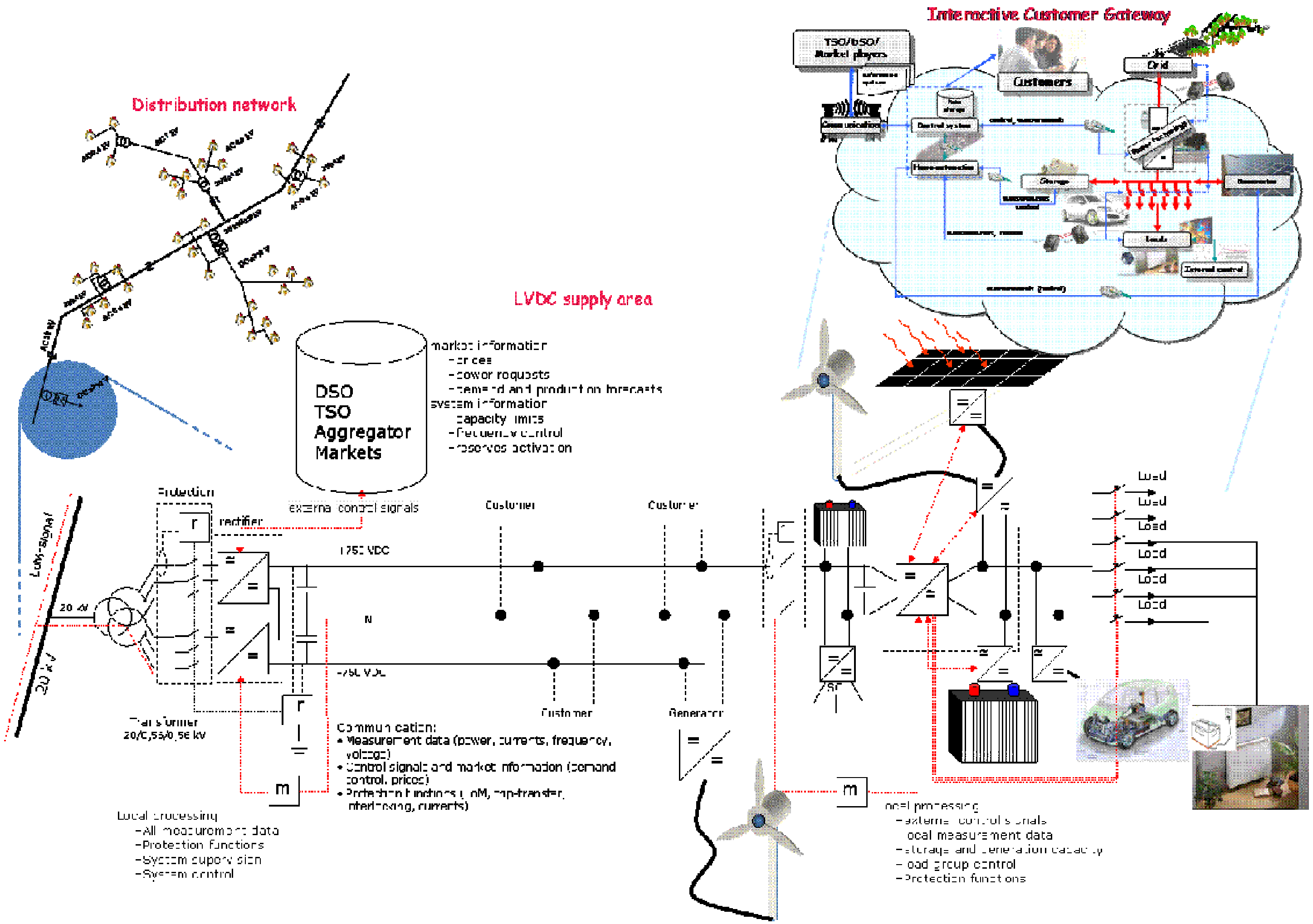
- Objectives of market players and related requirements for the system development

End-customer / Consumer	TSO
✓ Safe use of electricity ✓ Continuous use of electricity ✓ Minimisation of energy costs ✓ Connection of own generators ✓ Connection and free use of energy storages	✓ Power balance management ✓ Power reserve management ✓ System security management ✓ Load profile management ✓ Elasticity(* profile management
Electricity sales	**DSO**
✓ Billing information management ✓ Trade optimisation ✓ Power demand management ✓ Load profile management ✓ Elasticity(* profile management ✓ Forecasting of distributed generation	✓ Billing information management ✓ Network capacity management ✓ Power demand management ✓ Load profile management ✓ Elasticity profile management ✓ Supply security management ✓ Voltage quality management ✓ Electrical safety

*) How elastic is the power demand of a customer or a group of customers seen from the utility grid side of the customer interface with respect to market situation or electro-technical situation of the grid/power system.

Concept of LVDC microgrid



Concept of LVDC microgrid

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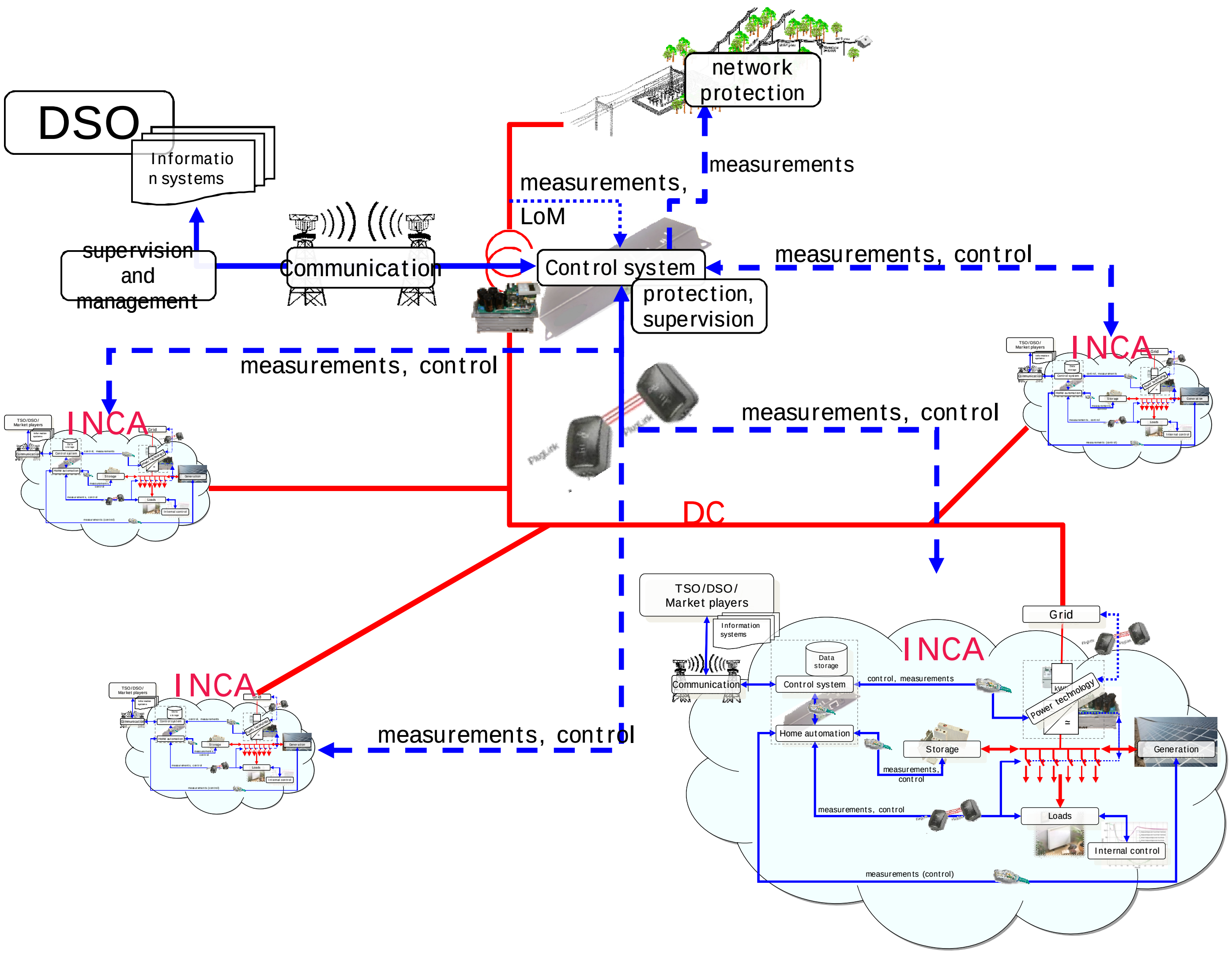
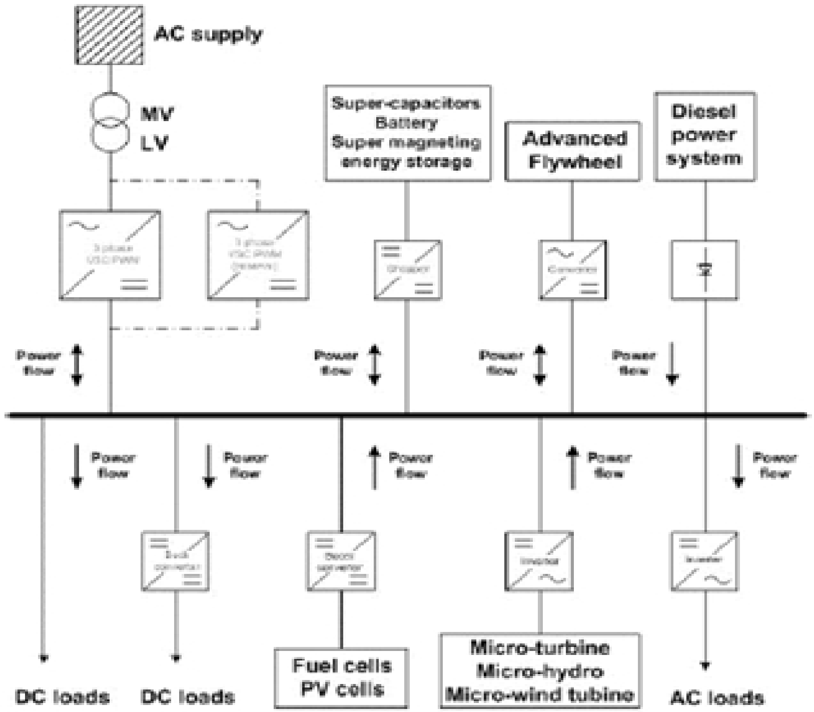
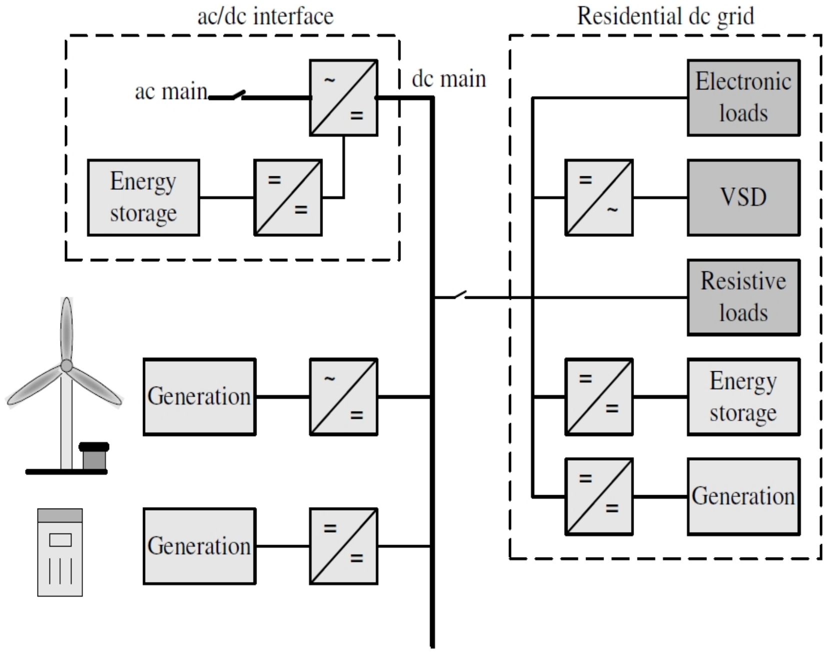


DC-grid models



a)

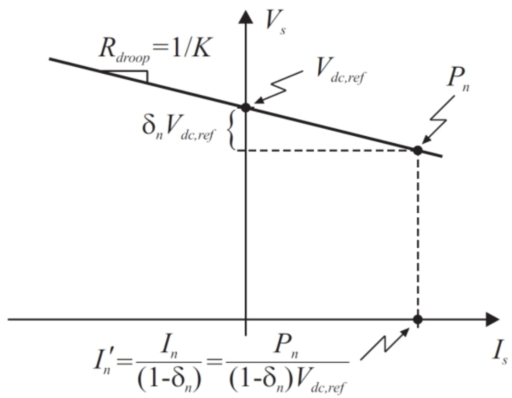


b)

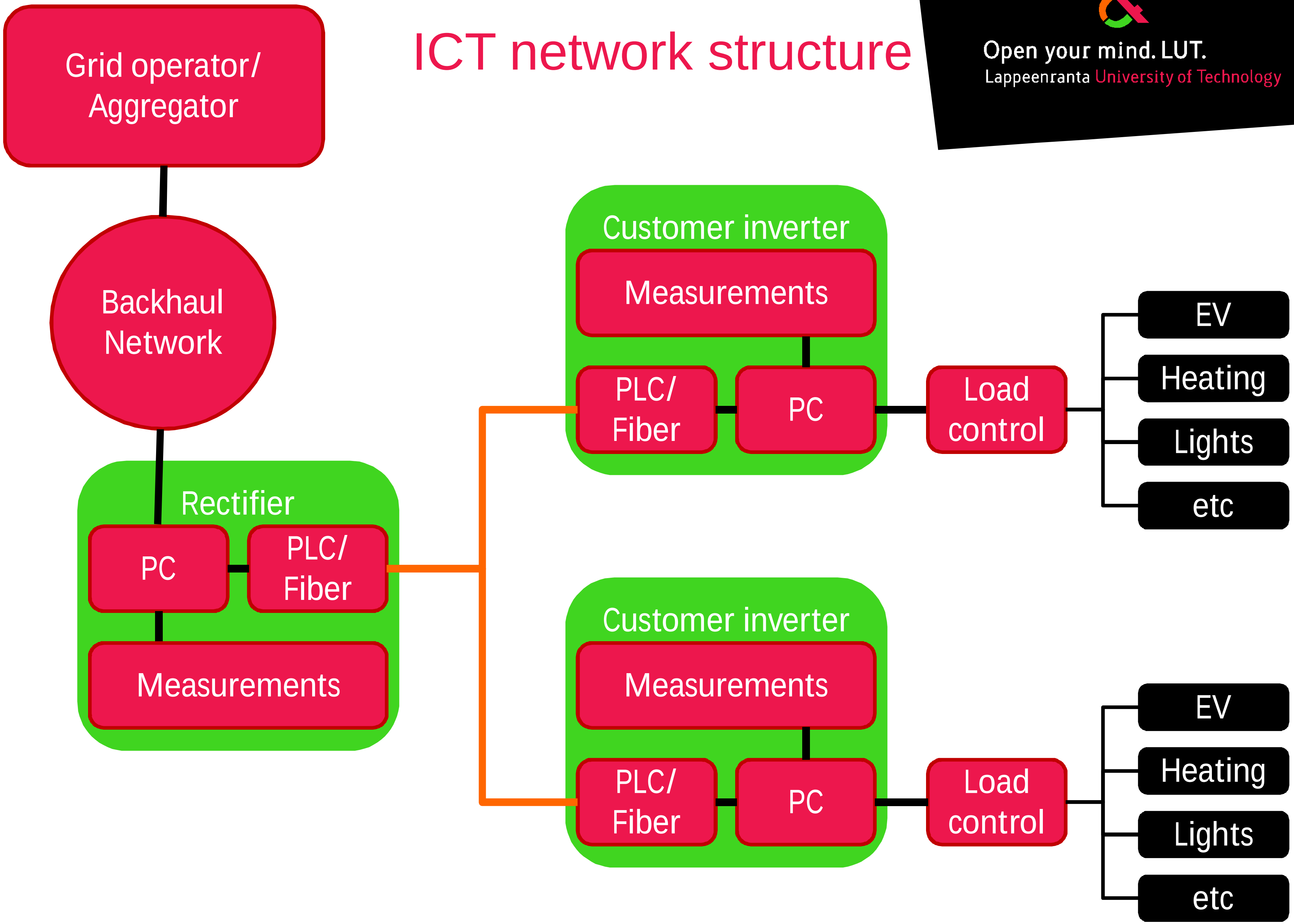
DC-microgrid models by a) Brenna et al., 2006 and b) Nilson, 2005.

DC-grid

- LVDC-grid forms a natural microgrid where loads and microproduction can be installed. Because of the rectifier, it can be easily disconnected from and connected back to the MV network. Stability of the DC-network can be maintained by measuring the DC-voltage, applying voltage droop method, controlling generator units and loads
- Controlling the power of all generator units is not effective. Instead, demand control can be executed rapidly.
- The need of the load control can be reduced by installing energy storages in the microgrid.
- In addition to control of the each generator and load unit, DC-grid requires system stage control, which secures that the unit control will not make the grid oscillate.
- The information network in LVDC-system helps to carry out the control and protection system in microgrid operations.



ICT network structure



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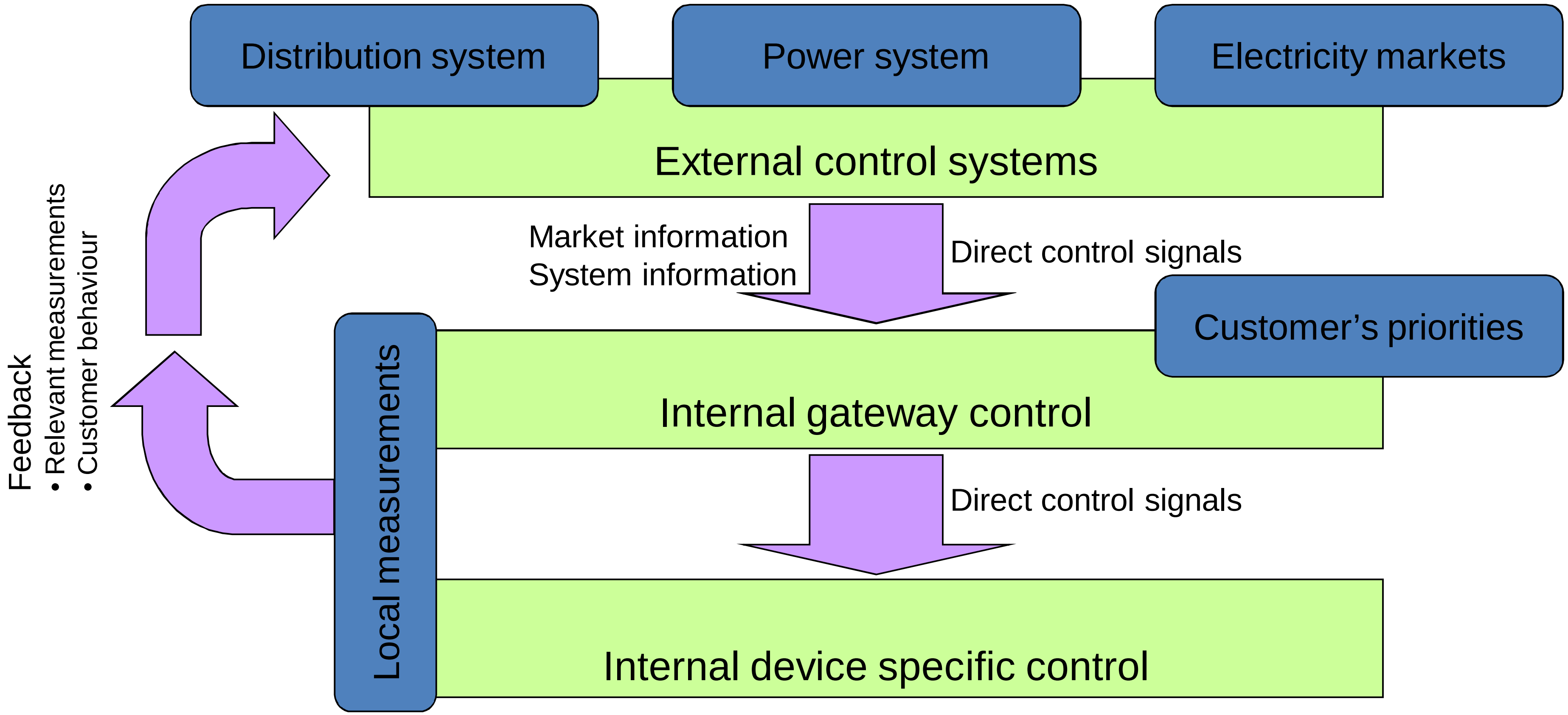
Critical data transfers

- Measurement data
  - Phase voltages: RMS & Peak
  - Phase currents: RMS & Peak
  - Neutral current: RMS & Peak
  - DC voltage
  - DC current
  - Current linkage
  - IGBT temperature
  - Case temperature
  - Harmonic voltages

- LVDC-link data
  - Voltage dip
  - On service
  - System on halt
  - System startup
  - Normal conditions
  - Interuptions
  - Measurement data

Overall control structure



Main controls

- Local actions
  - Related with consumption and customer decicions
    - Load control
      - *Lowering voltage*
      - *Switching off loads (heating, sauna, etc)*
      - *Energy storage control*
      - *Intelligence charging of electric car*
        - *Charging/discharging if necessary*
  - Voltage quality control
  - Requires local optimistaion algorithm combining the external inputs and local information
    - *Adaptive load models*
    - *Measurement data storaging*
- Remote actions
  - Related with grid owner/electricity seller
  - Load control
    - *Direct signals possible (voltage level, load switching, etc.)*
    - *Normally done by guiding the decision making internally in customer interfaces*
      - *permission for EV charging/discharging*
      - *Direct power intake limits*
      - *Electric energy price information (hourly prices+15 min. prices)*
  - System supervision
    - *Electric safety*

Control system 1/3

- There are three main levels in the control system of the interactive customer gateway.
  - The first and the highest level control is formed by the algorithms in the information systems of the DSO, TSO and the energy suppliers.
  - The second level of control is the main control of the customer gateway.
  - The third control level is formed by the individual control algorithms of the active devices in the customer's network, like building automation, generator interface converters, AMR meter, sensitive heating system control, active voltage controller, etc.
- The two upper level controls are the most important for achieving coordinated interoperation of the interactive customer gateway.
- The execution of the control signals given by the two upper levels are dependent from the operation of the third control level.
- The control algorithms are based on operations models that define the basic actions to in each situation.
  - The control algorithms should be adaptive

Control system 2/3

- The main tasks of the first (external) and second (internal) level control algorithms are:
  - Recognition of active resources and creation of patterns for customer behaviour (internal)
  - Classification of the resources according to their elasticity, applicability and random variation (internal and external)
  - Creation of customer specific load and elasticity profiles (internal)
  - Short-term estimation of loads and local generation (internal)
  - Short-term estimation of market behaviour (external)
  - Optimisation of system loads for different market players based on measurement data, short-term forecasts, and load and elasticity profiles (external)
  - Optimisation of load profiles of individual customers based on given market information, direct control signals, customer behaviour and short-term forecasts (internal)
  - Recognition and finding solutions for power quality problems (external and internal)

Control system 3/3

- The main target of the third control level is to take care of the execution of the upper level control signals in boundaries of momentary state of the system locally.
- The third and second level controls have to work seamlessly together so that when the local situation changes, i.e. customer behaves unexpectedly or an disturbance occur somewhere in the system, the first operations are to stabilise the situation and to inform external actors of the situation and of the actions by the gateway due to it, so that the harm caused either to external market players and/or to the customer are minimised.

Case: EV control

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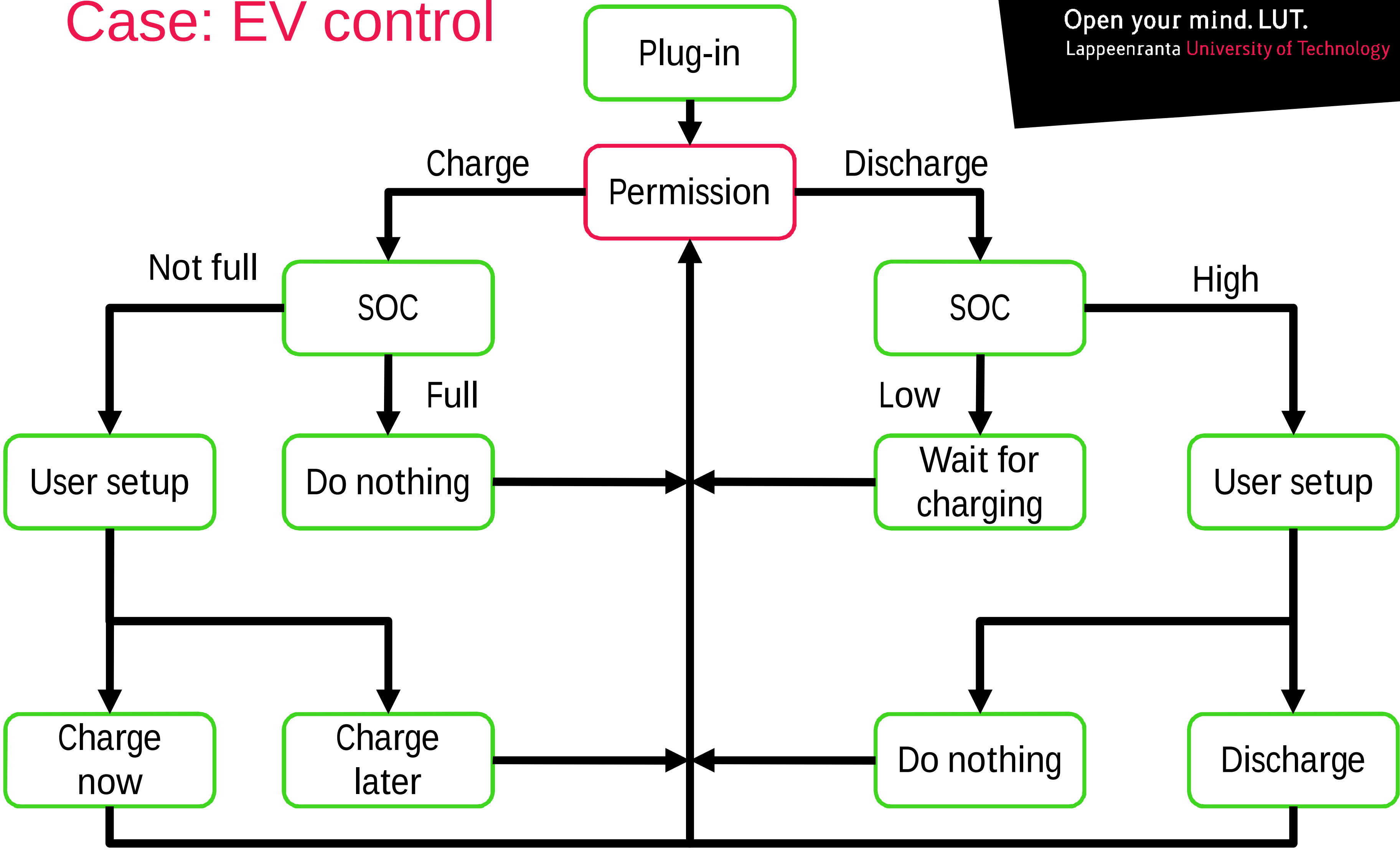
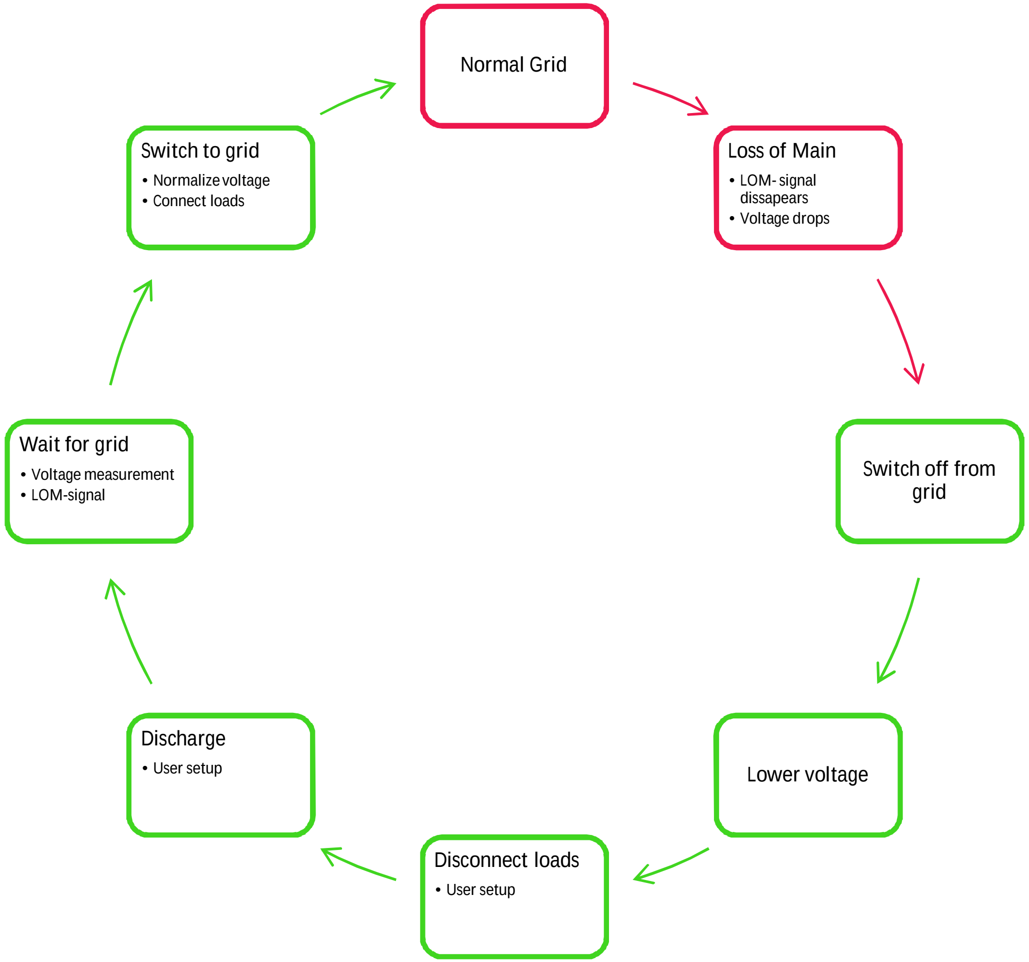


Case: Island operation



Case: Green Campus - http://www.lut.fi/fi/green-campus/sivut/default.aspx