Business from technology

Application of storage systems for Smart Grid purposes

EERA Smart Grids R&D Workshop

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Kari Mäki

VTT

Contents and approach

- Use of energy storages in Smart Grid context
  - Storage characteristics
  - Potential applications and use cases
  - Grid ancillary services
  - Modelling and simulation of storage systems

- Grid point of view approach applied
  - Benefits and requirements
  - Modelling interface at grid connection point – ensuring correct operation towards grid, not necessary to model physical phenomena beyound

- Results based on national SGEM (Smart Grids and Energy Markets) research program and European IoE (Internet of Energy) project

Applications in distribution network

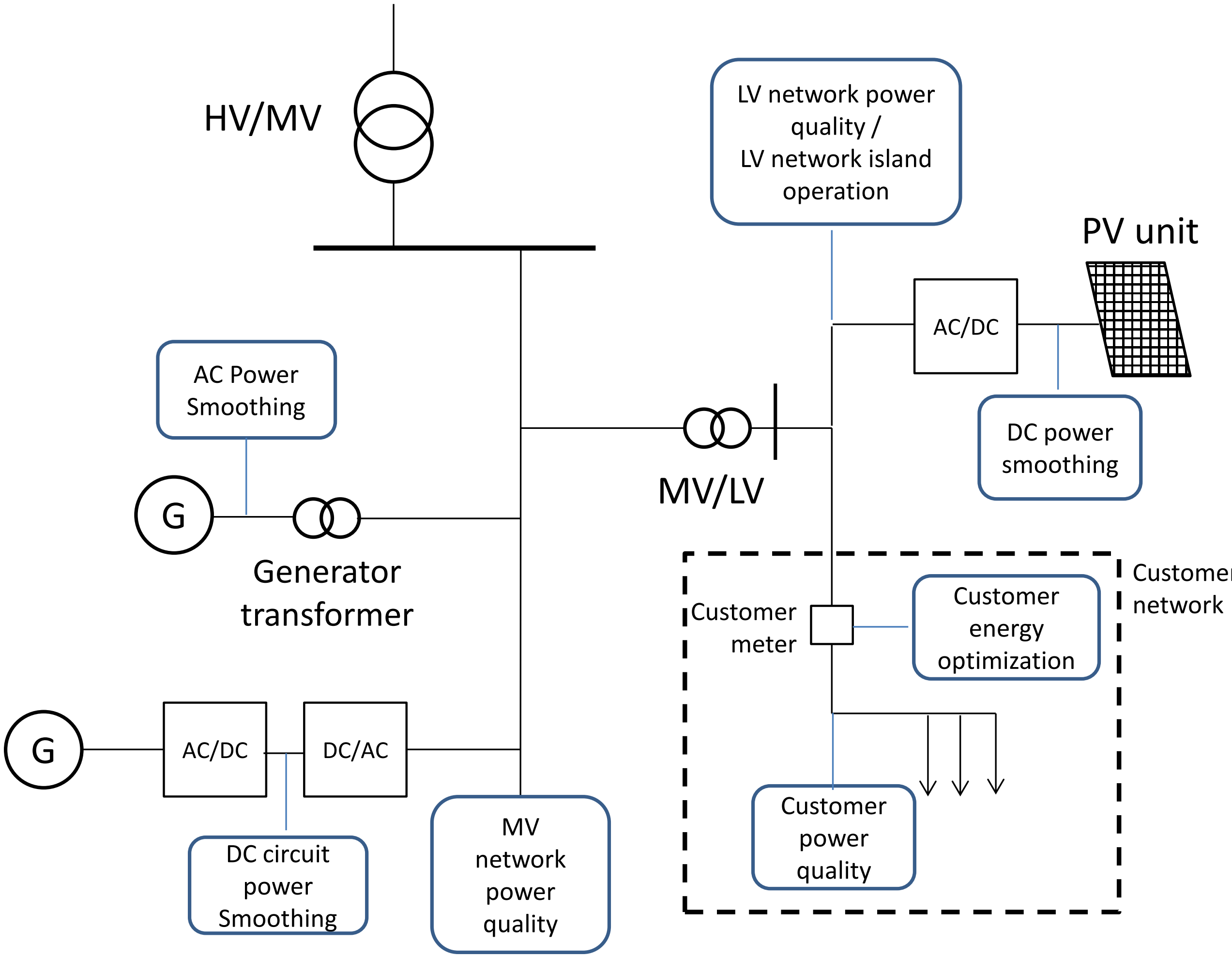
- Drivers
  - Amount of intermittent RES generation
    - Storage enabling more efficient integration
  - Need for better service reliability
    - Avoiding service interruptions
    - Improving customer power quality
  - Amount of electric vehicles
    - Potential for smart charging and vehicle to grid (V2G) integration
  - Customer-level applications
    - Economical use of dynamic tariffs
    - Optimization of microgeneration
    - Local back-up power

→ ”Significant extension of demand side management - from controllable load to controllable combination of load and generation”

Applications in distribution network

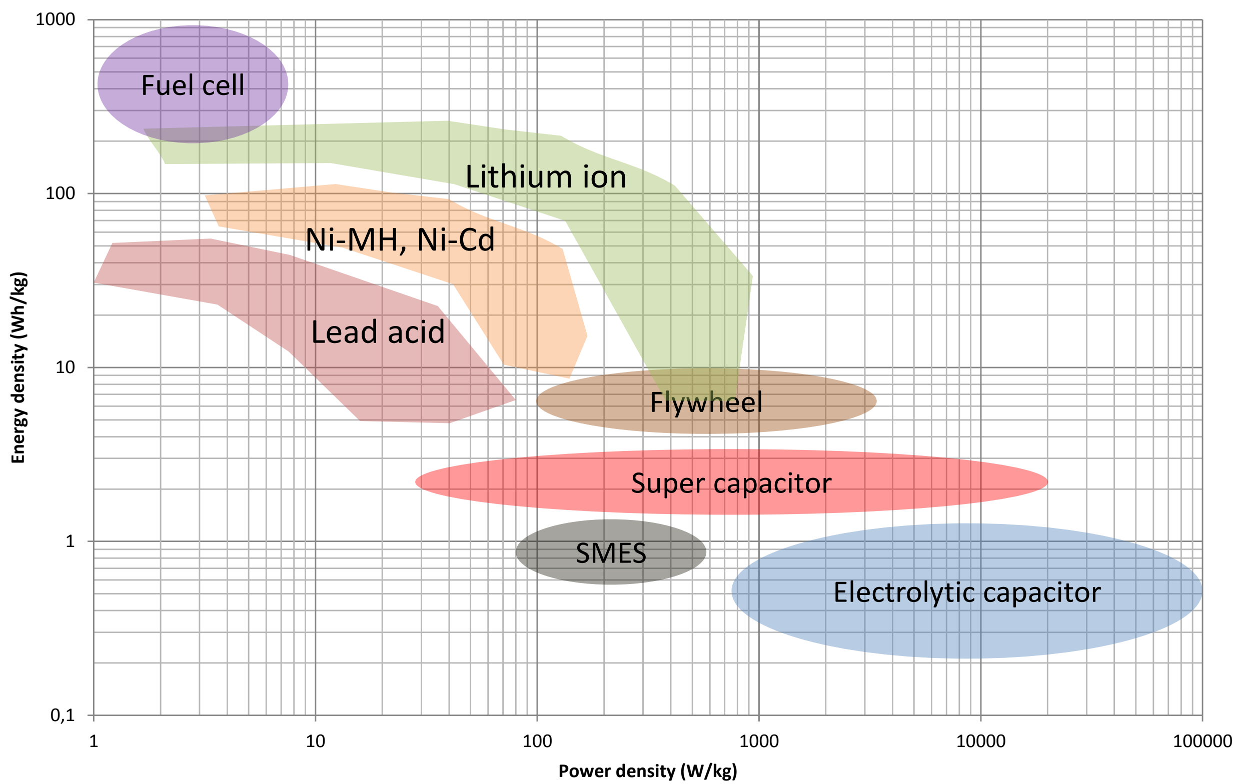
- Potential energy storage applications in distribution network
  - Network power quality improvement
  - Power generation smoothing – especially RES
  - Grid load smoothing / peak shaving
  - Temporary islanded operation of public grid or customer appliances
  - Customer-level energy optimization
  - Customer-level quality improvement

Applications in distribution network



Applications in distribution network

- Different storage types – different characteristics
  - Suitable application areas can be defined
  - Hybrid systems can be beneficial

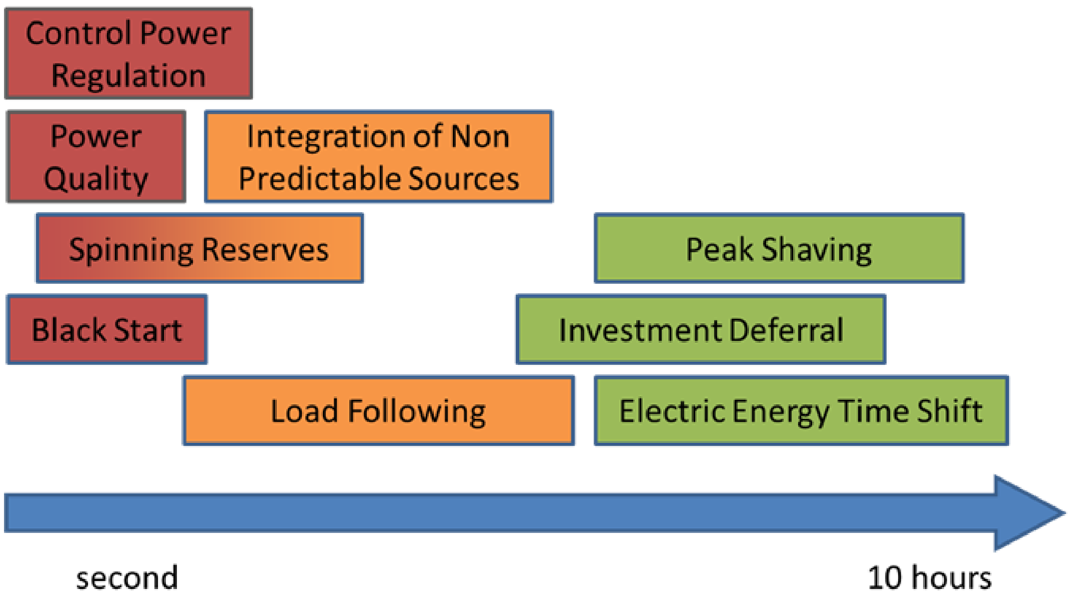


Applications in distribution network

- Energy system needs according to operation time scale
  - *Power quality improvement - from microseconds to seconds.* Suitable for local applications where sensitive loads are present.
  - *Power balance smoothing - from seconds to hours.* Suitable especially for integration of renewable energies like wind power and PV. Also for load peak shaving.
  - *Diurnal variation smoothing – scale of hours.* This usually means variation between day and night.
  - *Seasonal smoothing - from days to months.* Especially between seasons. Difficult to achieve currently. Primarily heat storage applications?
  - *Grid ancillary services - from minutes to days or even to months.* Grid state related services agreed between network operator and storage owner.

Applications in distribution network

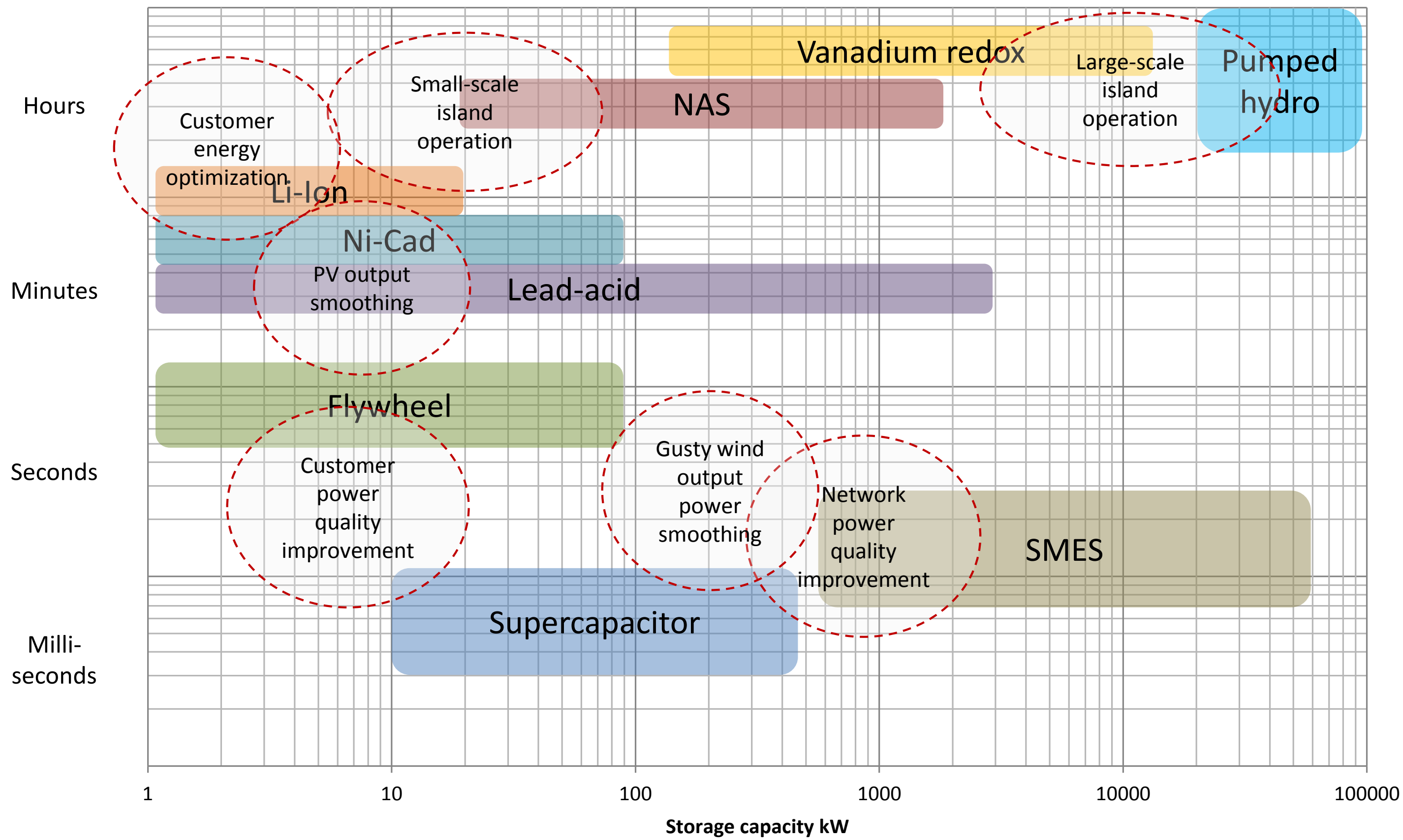
- Energy system needs according to operation time scale



- Time response requirements as defined in IoE project.

Applications in distribution network

- Different storage types – different application areas



Grid ancillary services

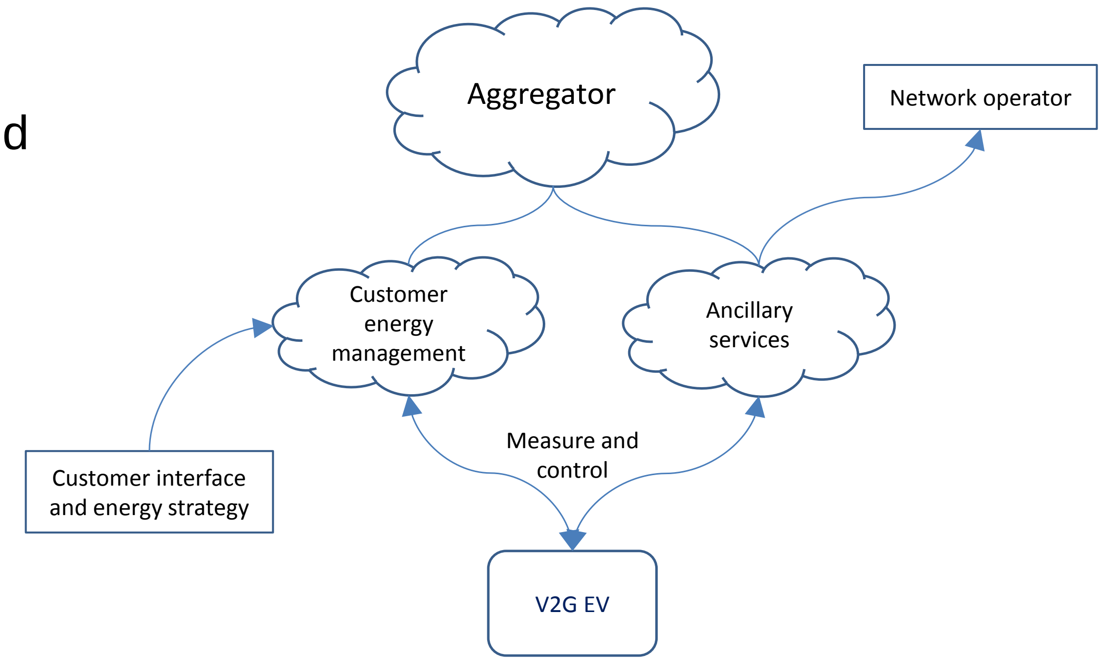
- Most of the technical solutions mentioned could be offered to local grid operator as ancillary services
  - Local voltage control
  - Local power quality management
  - Local islanded operation
  - Local peak shaving

- Providing ancillary services requires efficient co-operation
  - Communication and control of storage device
  - Integration to network operator’s SCADA and other systems
  - Measurements, agreements etc.

Grid ancillary services

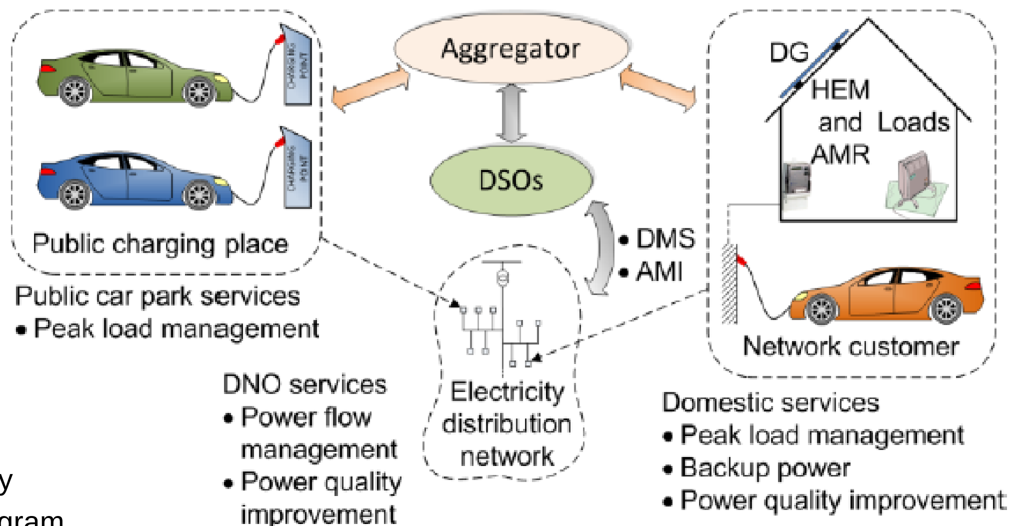
- Aggregator service is a potential solution
  - Aggregator combines multiple small units
  - Suitable especially for EVs
  - Combination of controllable loads, microgeneration, storages, etc.
  - *Aggregate impact of small units can be significant*

- Aggregator could be serving both local grid and customer's own energy management



Grid ancillary services

- EVs as ancillary service providers
  - Significant mass of storage units distributed in the network
  - Huge potential for local network management
  - Efficient load control possibility
- Drawbacks / open issues
  - Battery lifetime with charge/discharge cycles
  - Normal EV usage needs



Picture: Tampere University of Technology / SGEM program

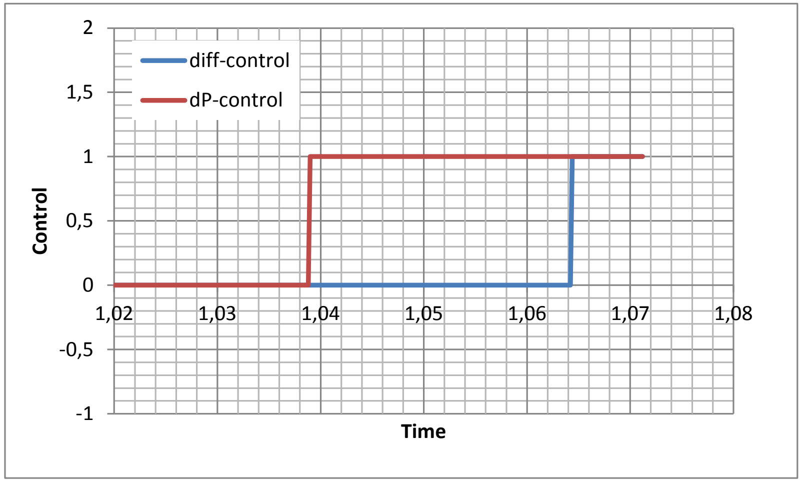
Control logics for RES integration

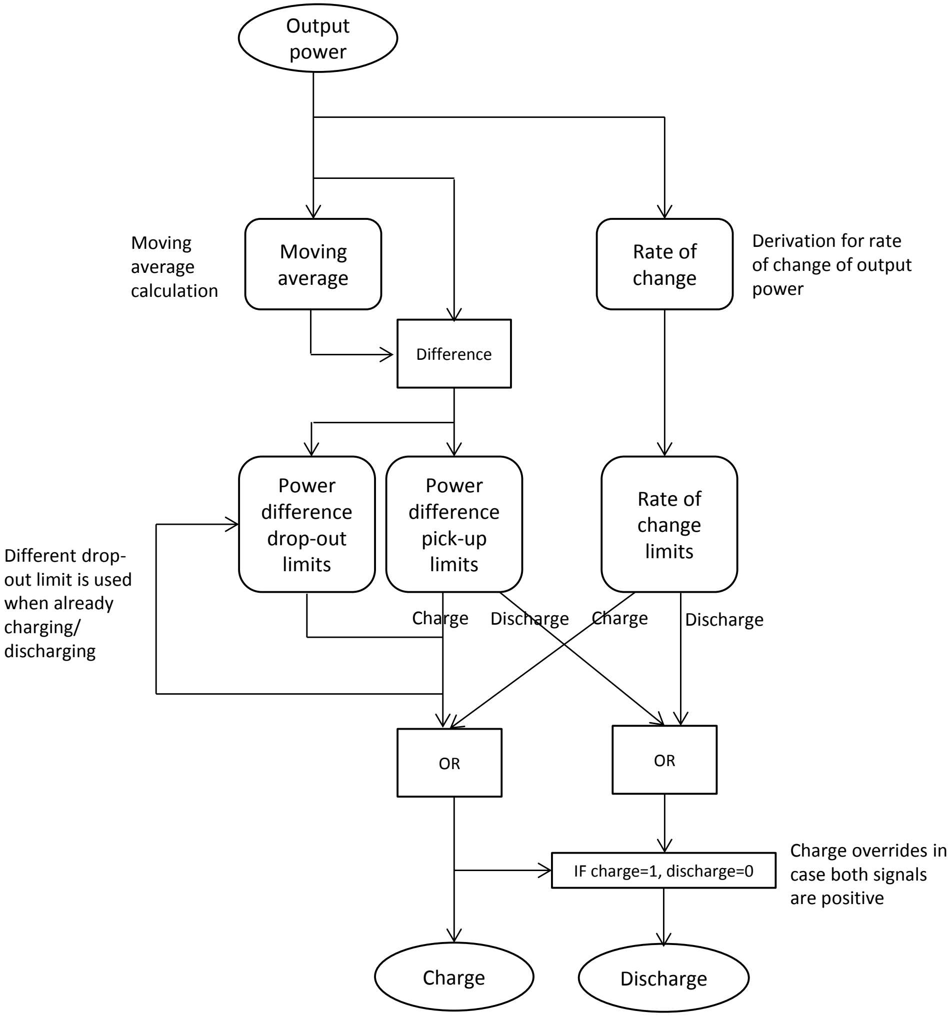
- Possibilities:
  - Smoothing power output
  - Overriding grid capacity restrictions – storing excess energy
  - Reactive power compensation for voltage control purposes
  - Support for fulfilling fault ride through (FRT) requirements

- Requirements:
  - Ability to monitor connection point state
  - Ability to react to alternating power output (fast yet stable…)

Control logics for RES integration

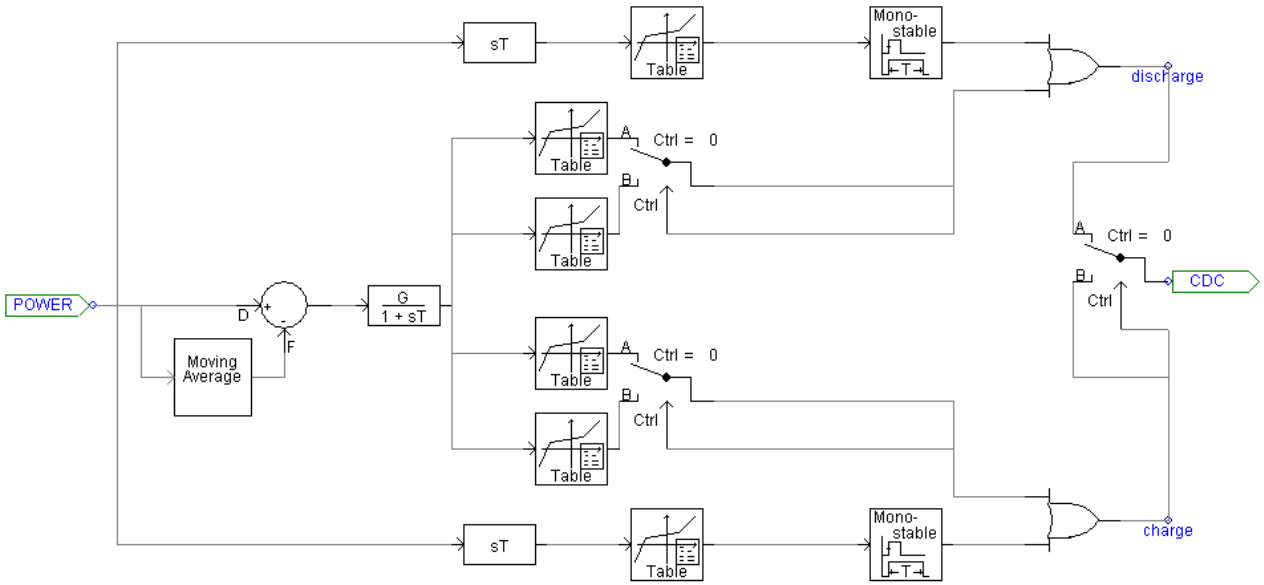
- Development of charge/discharge control logics for RES use
  - Including output power rate of change monitoring for responding to quick changes
  - Separate pick-up and drop-off limits to avoid repeating controls





Control logics for RES integration

- Development of charge/discharge control logics for RES use



Control logics for RES integration

- Use of storage for smoothing PV output (IoE project)

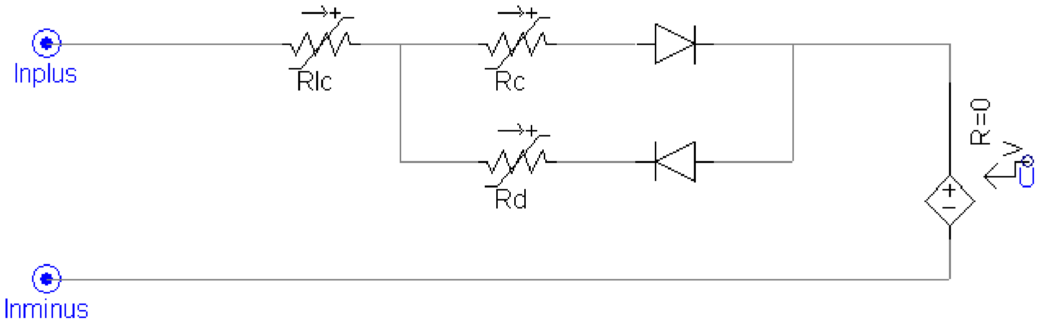
Modeling for power system studies

- Grid-focused point of view: modeling behavior towards grid rather than modeling physical phenomena itself
- Generalities
  - Controllable DC voltage source
    - (Exceptions: SMES coil current, flywheel mechanical inertia, …)
  - Controllable impedances for modeling dynamic behavior
  - State of charge (SOC) with integral calculation or similar
  - Temperature etc. must be included in the equations

→ Electrical circuit is normally trivial, but <u>the key</u> is in modeling dynamic behavior with impedances and voltage reference

Modeling for power system studies

- Modeling example: Sodium Sulfur (NaS) battery
- Equivalent circuit:
  - Rlc – lifecycle resistance
  - Rc – charge resistance
  - Rd – discharge resistance

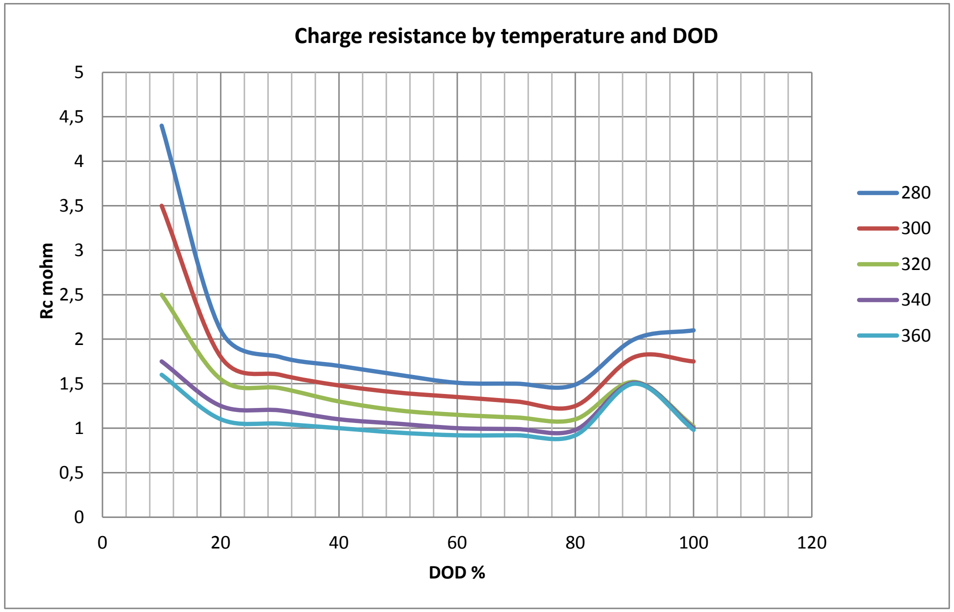


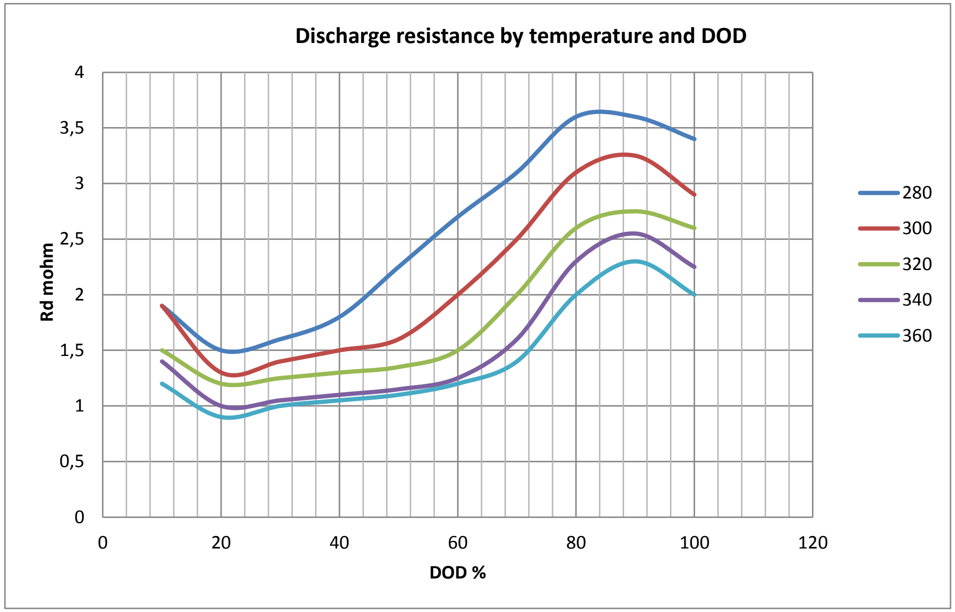
- SOC calculation:

$$SOC = 1 - \frac{Ah_{rated} - \int I_{DC}\,dt}{Ah_{rated}}$$

Modeling for power system studies

- Modeling example: Sodium Sulfur (NaS) battery
  - Characteristics for charge and discharge resistances
  - Temperature impact included

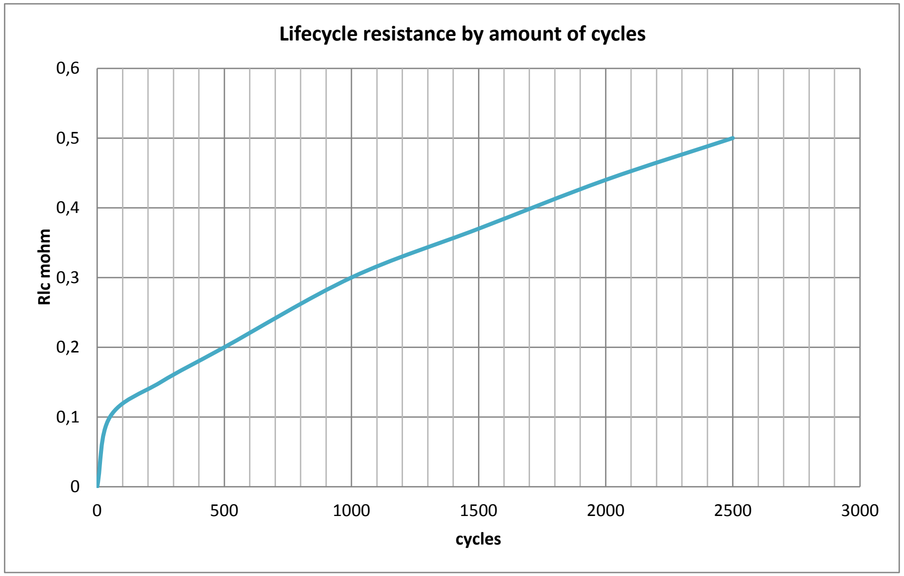


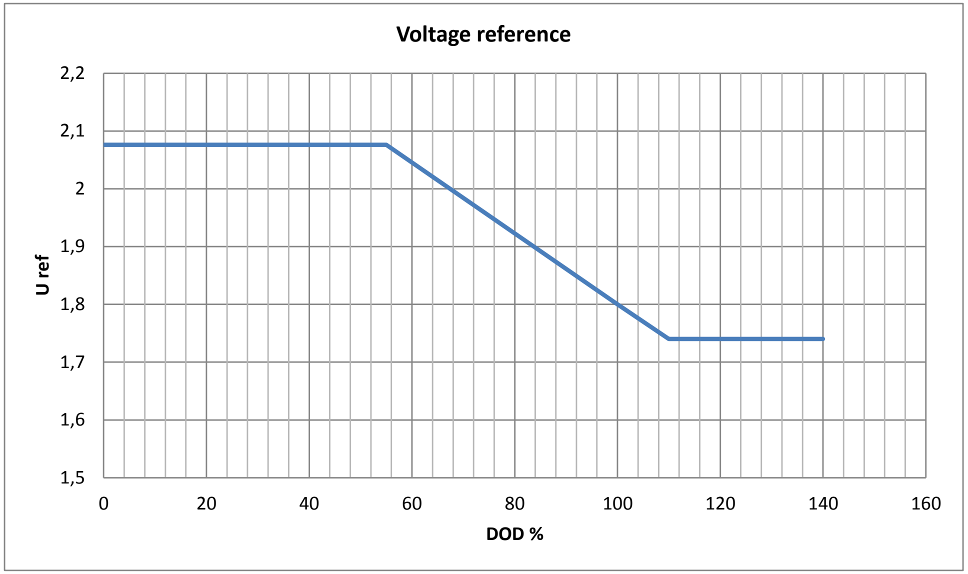


$$DOD = 1 - SOC$$

Modeling for power system studies

- Modeling example: Sodium Sulfur (NaS) battery
  - Characteristics for lifecycle resistance and voltage reference

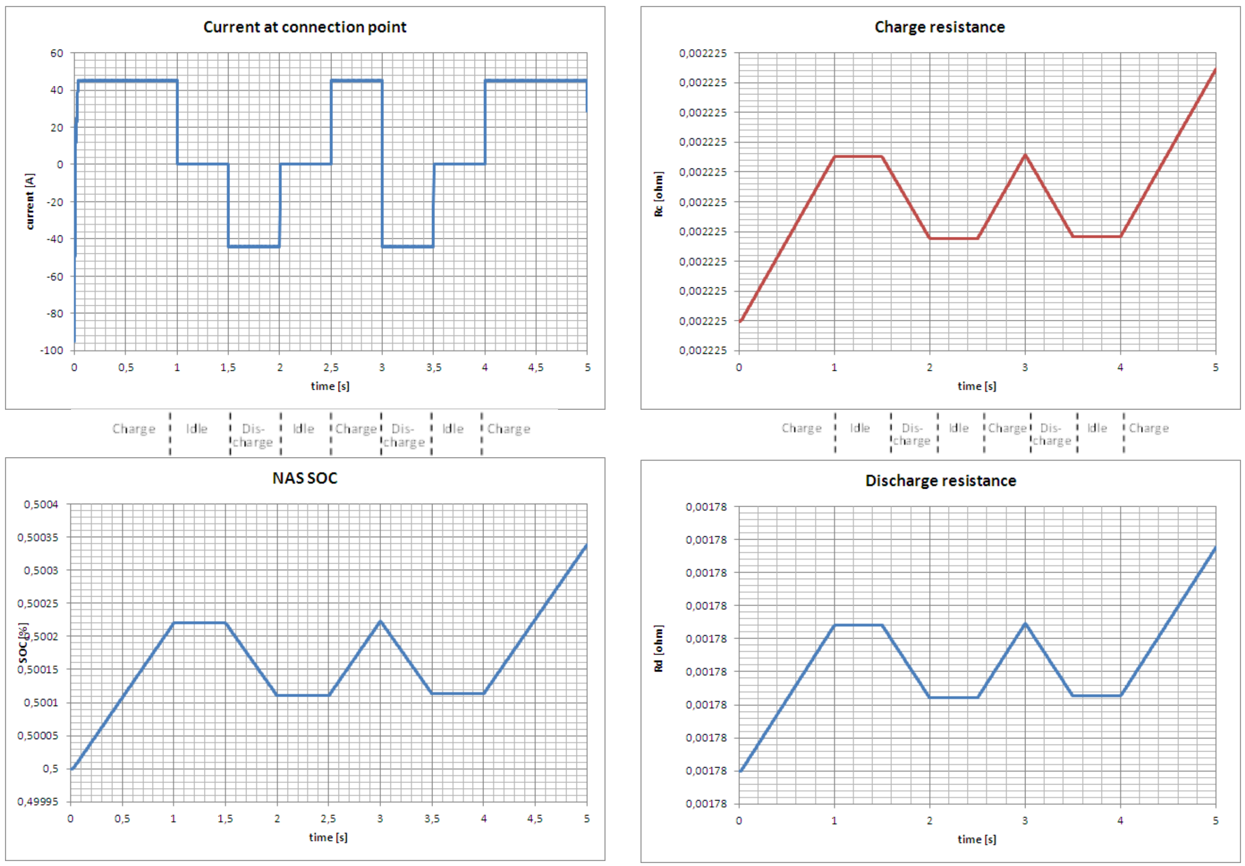




$$DOD = 1 - SOC$$

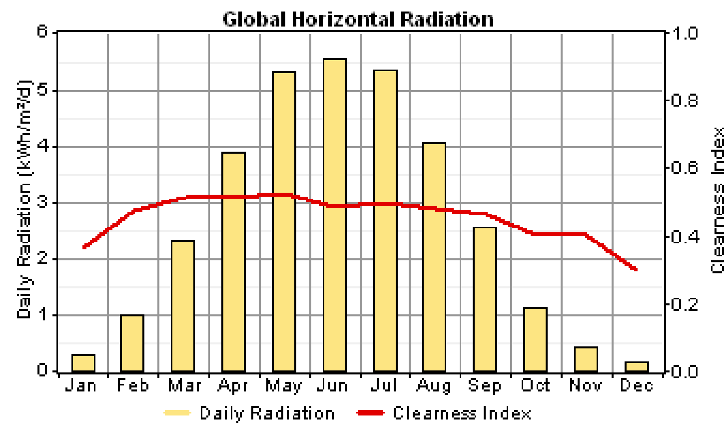
Modeling for power system studies

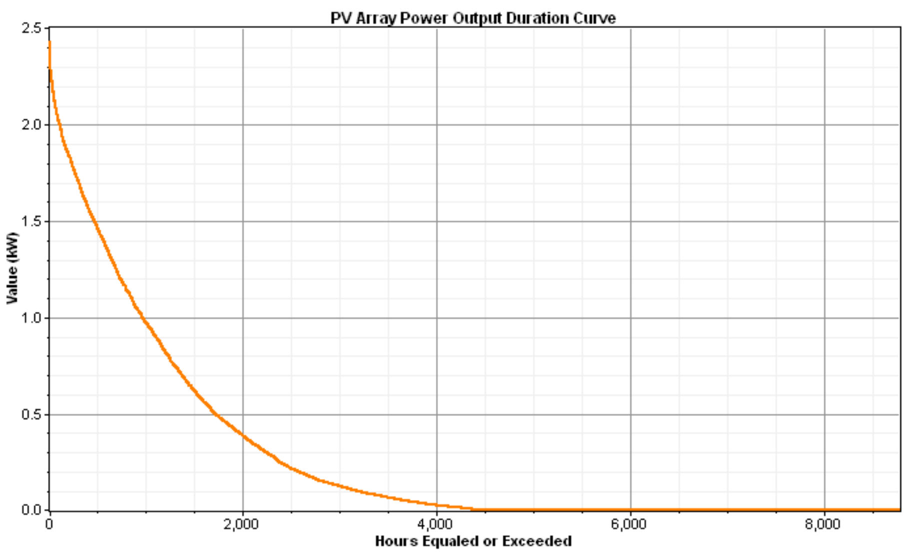
- Modeling example: Sodium Sulfur (NaS) battery
  - Example simulations

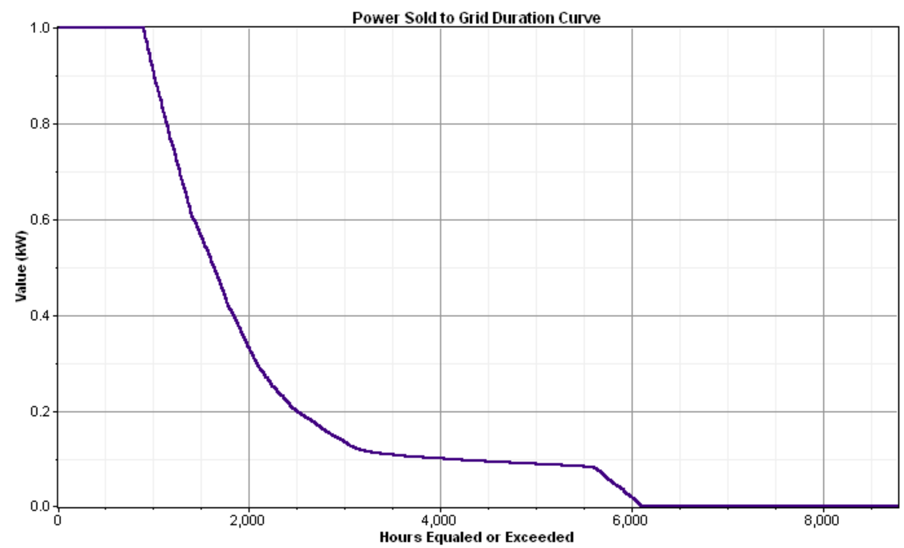


Case study

- PV output smoothing in Nordic conditions
- Daily variation can be reduced
- Other methods needed for seasonal level







To conclude…

- Efficient storage units are needed in Smart Grids
- Different requirements according to the application
  - From power quality to seasonal variation
  - Different storage technologies to match different requirements
- EVs represent high potential
  - On customer-level as local applications
  - On network level as aggregated services

Thank You!

Kari Mäki
Senior Scientist, Dr.Tech.
Energy systems
VTT Technical Research Centre of Finland
Tel. +358 40 142 9785
kari.maki@vtt.fi

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