Charging of electric vehicles as reserves of power systems

eCharge –workpackage
ECV-seminar, TTY, 10.3.2015

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Smart Grids - future energy systems

- distributed energy resources with fully integrated network management

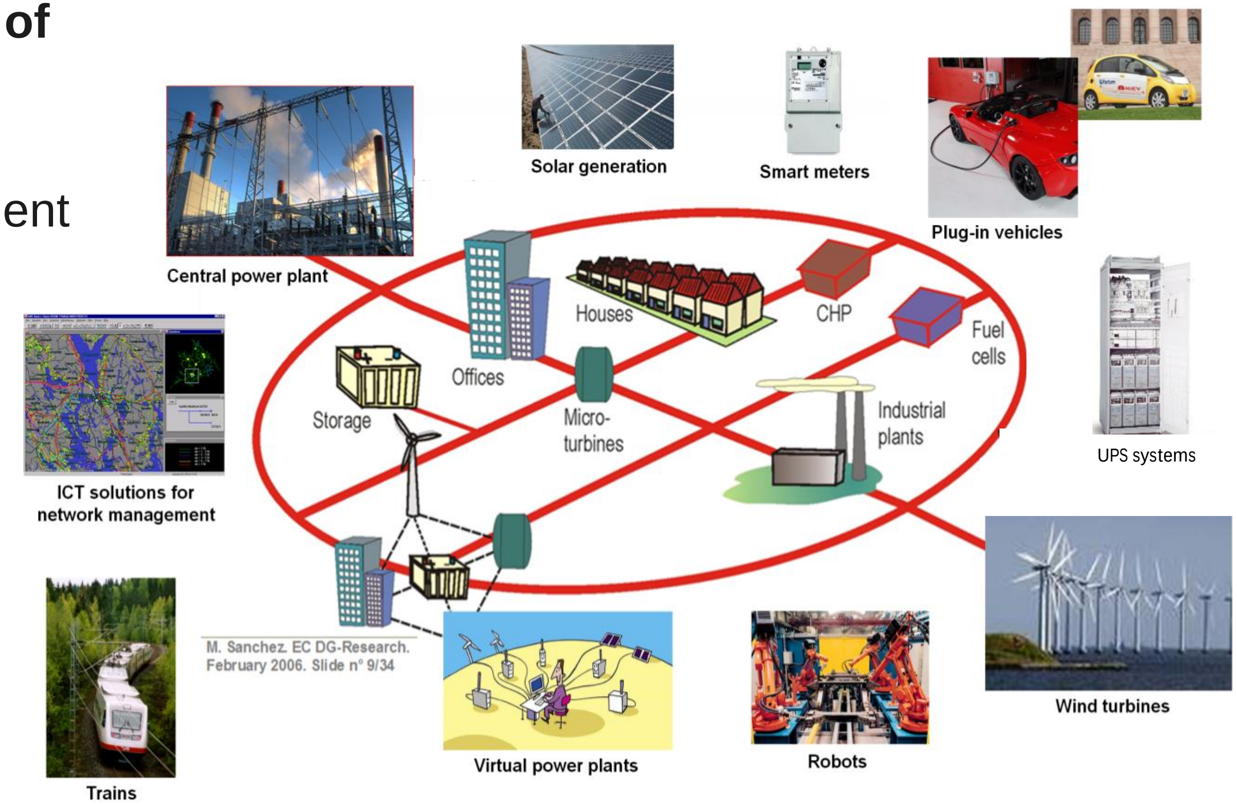
Smart grids has **two main functions**, which are challenges to the distribution system:

1) Enabler of energy-efficient and environmentally friendly open energy market

- interactive customer interface, integration of active resources, demand response, common market models and comprehensive ICT solutions

2) Critical infrastructure of society

- fault and major disturbance management
- self-healing networks
- island operation and microgrids



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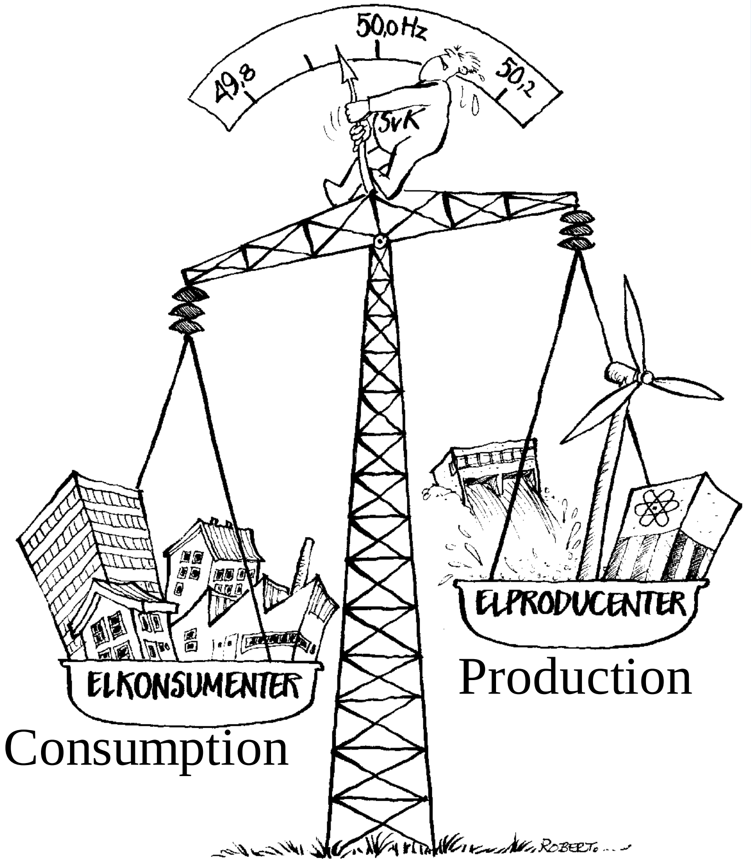
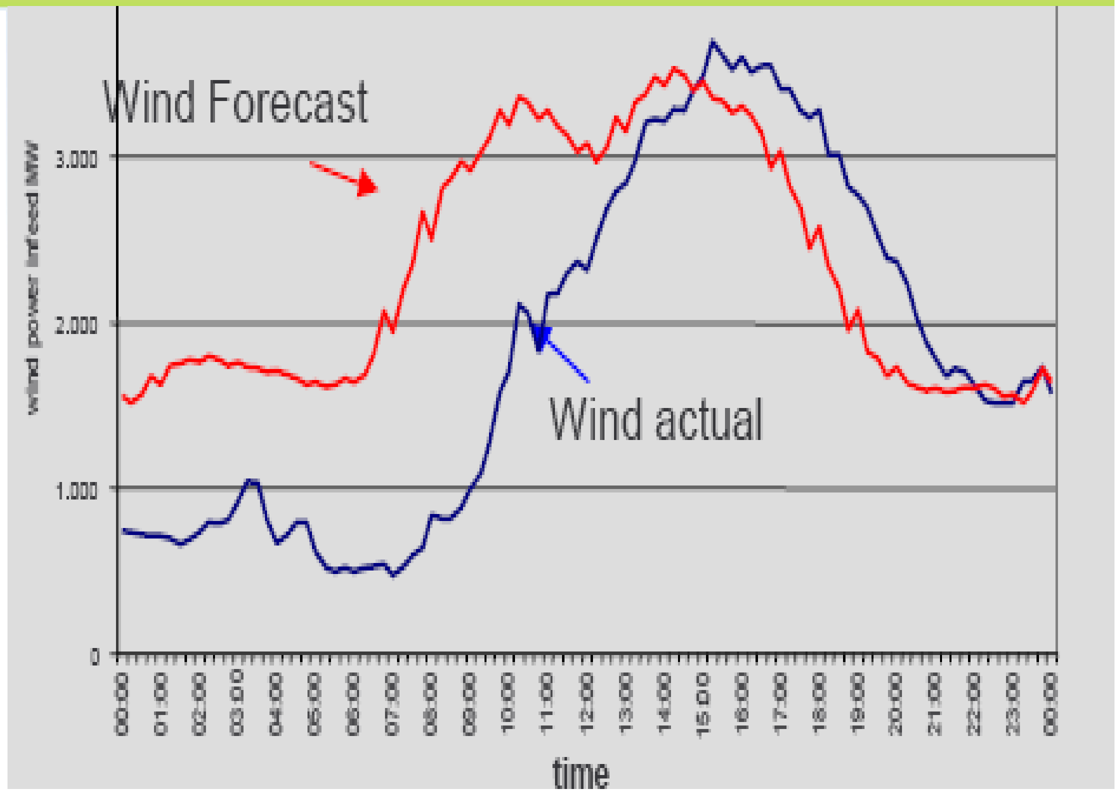
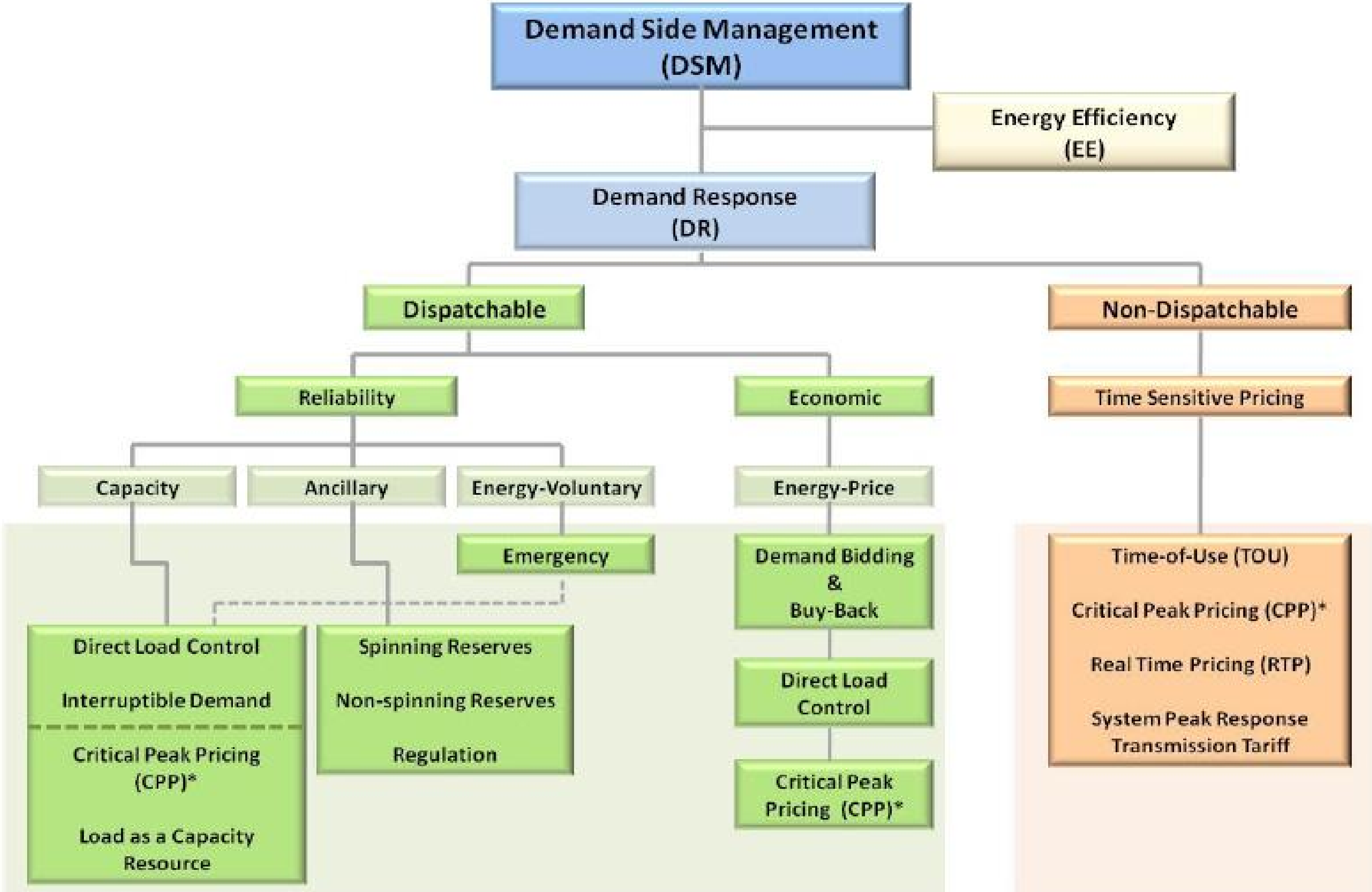
Challenge in integration of renewable energy sources - availability of emission free balance power





- Wind and solar power requires more balance power
- Smart Grid enables balance by interconnected networks and also by integrated active small resources

Demand Side Management (DSM) and Demand Response (DR)



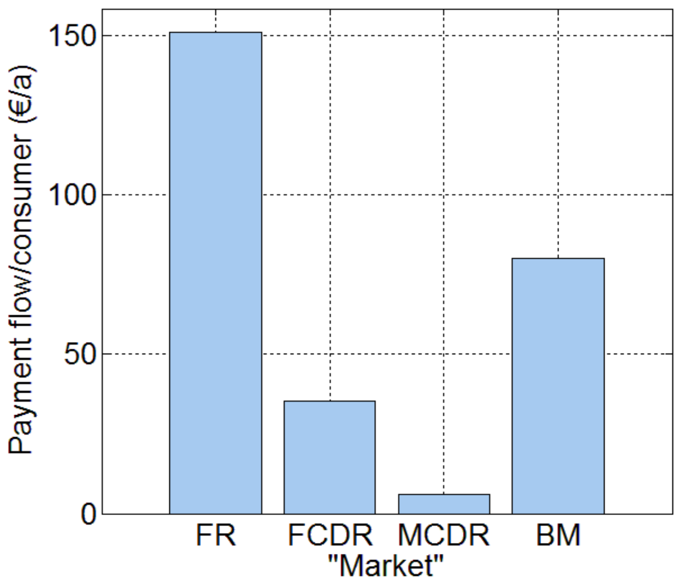
Reference: (Bartholomew, Callender, Hindes 2009)

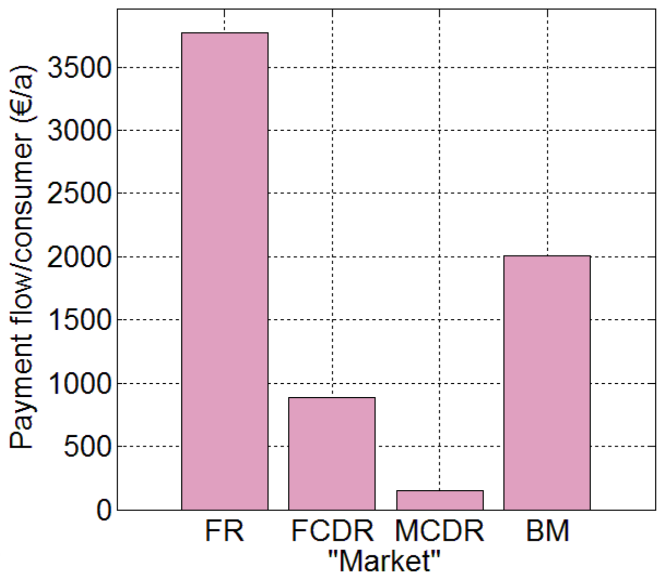
Using small resources in ancillary service markets

Two different cases are calculated
- small electricity consumers and
- medium electricity consumers

The “ancillary service markets” are
- frequency regulation (FR)
- frequency controlled disturbance reserves (FCDR)
- manually controlled disturbance reserves (MCDR)
- balancing market (BM).

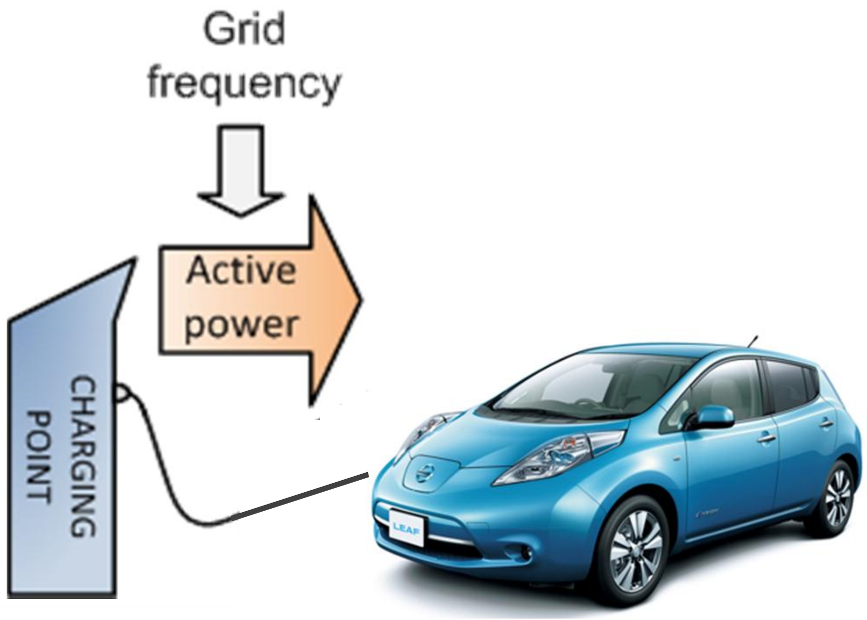
Case	Number of loads	Average annual mean power of the individual loads (kW)	Average peak power of individual loads (kW)*
Small consumers	10 000	1.2	10
Medium consumers	400	30	80





Frequency dependent charging

- Plug-in vehicles will be a remarkable load
- New load brings new challenges...but also opportunities → ancillary services
- Ancillary services provided by frequency dependence
  - frequency regulation, disturbance reserve, …
- Active power drawn by the charger is made dependent of locally measured grid frequency → new dynamic load

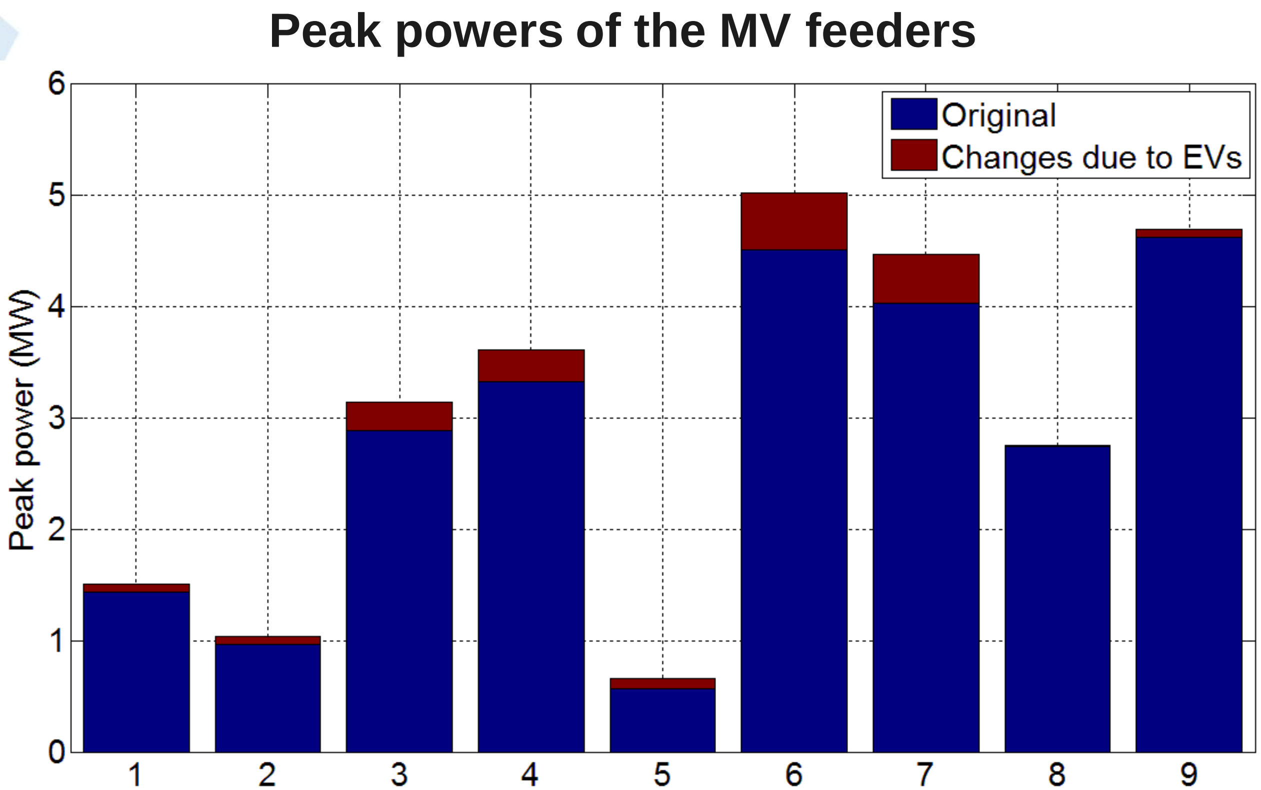


Electric vehicles as resources of Smart Grids

- Possible roles of EVs in Smart Grids
  - New load (charging)

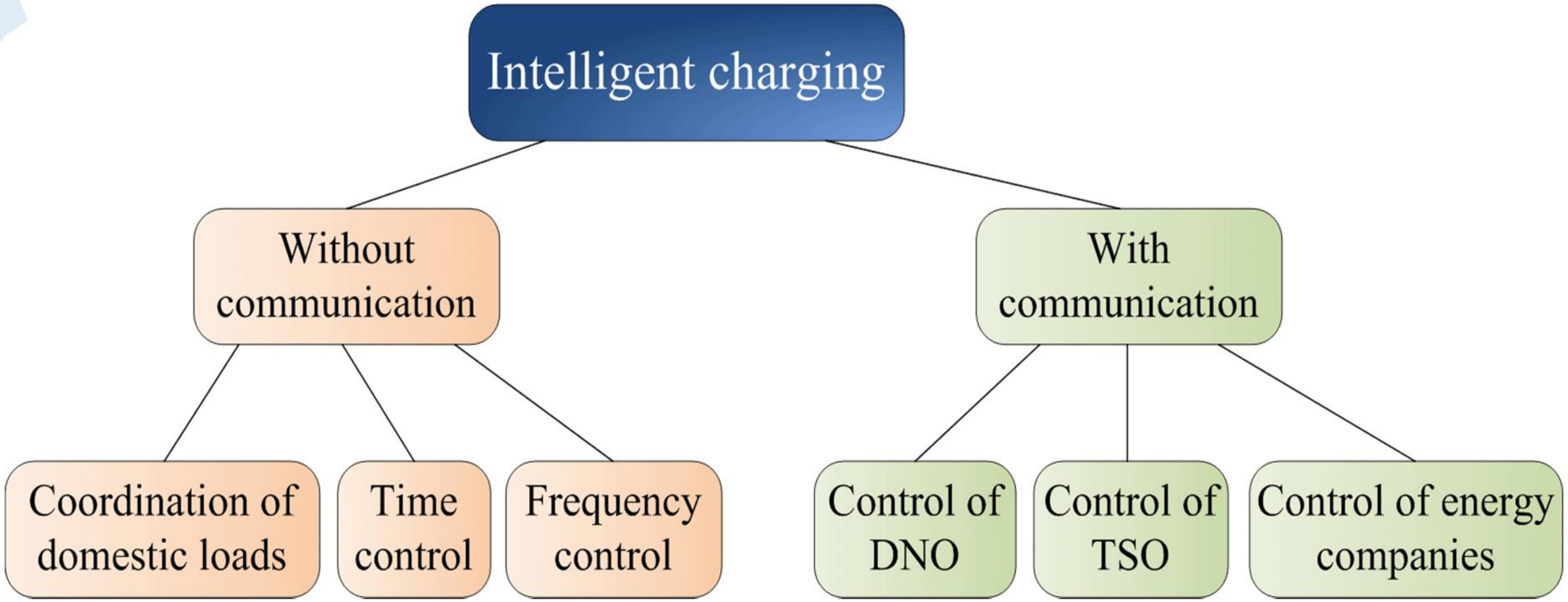
A simulated case study of distribution network

- Real distribution network supplied from 110/20 kV primary substation having 457 km 20 kV network and 793 km 0.4 kV network, 469 secondary substation and 7612 customer
- Roughly half of the customers have an EV with “dumb” and “slow” charging



Electric vehicles as resources of Smart Grids

- Possible roles of EVs in Smart Grids
  - New load (charging)
  - Controllable load
    - EV charging can be controlled at least as
      - on/off (~switch)
      - adjustment of charging current



Electric vehicles as resources of Smart Grids

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  - Controllable load
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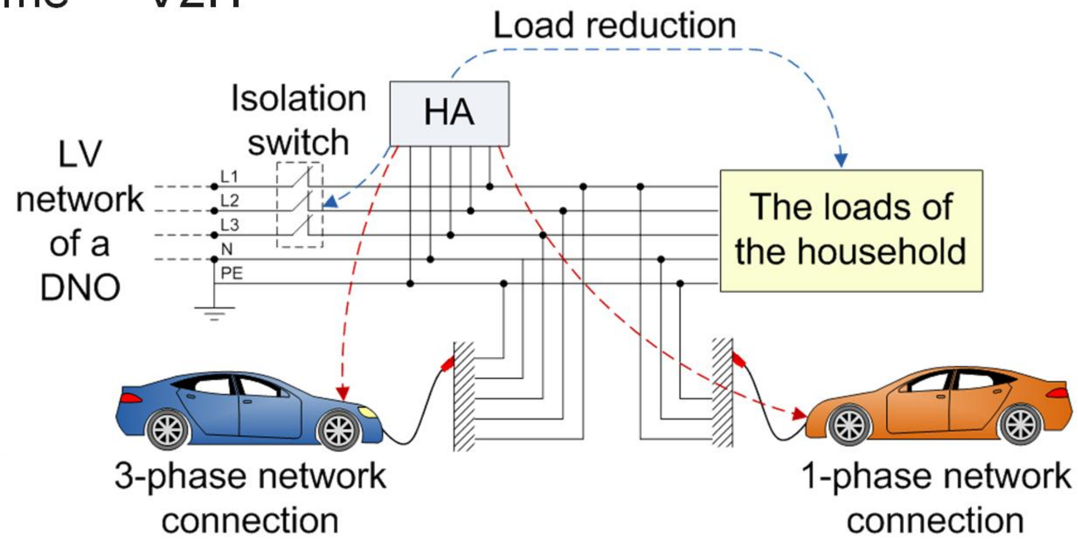
  - Controllable energy storage
    - Vehicle-to-grid – "V2G"
    - Vehicle-to-home – "V2H"

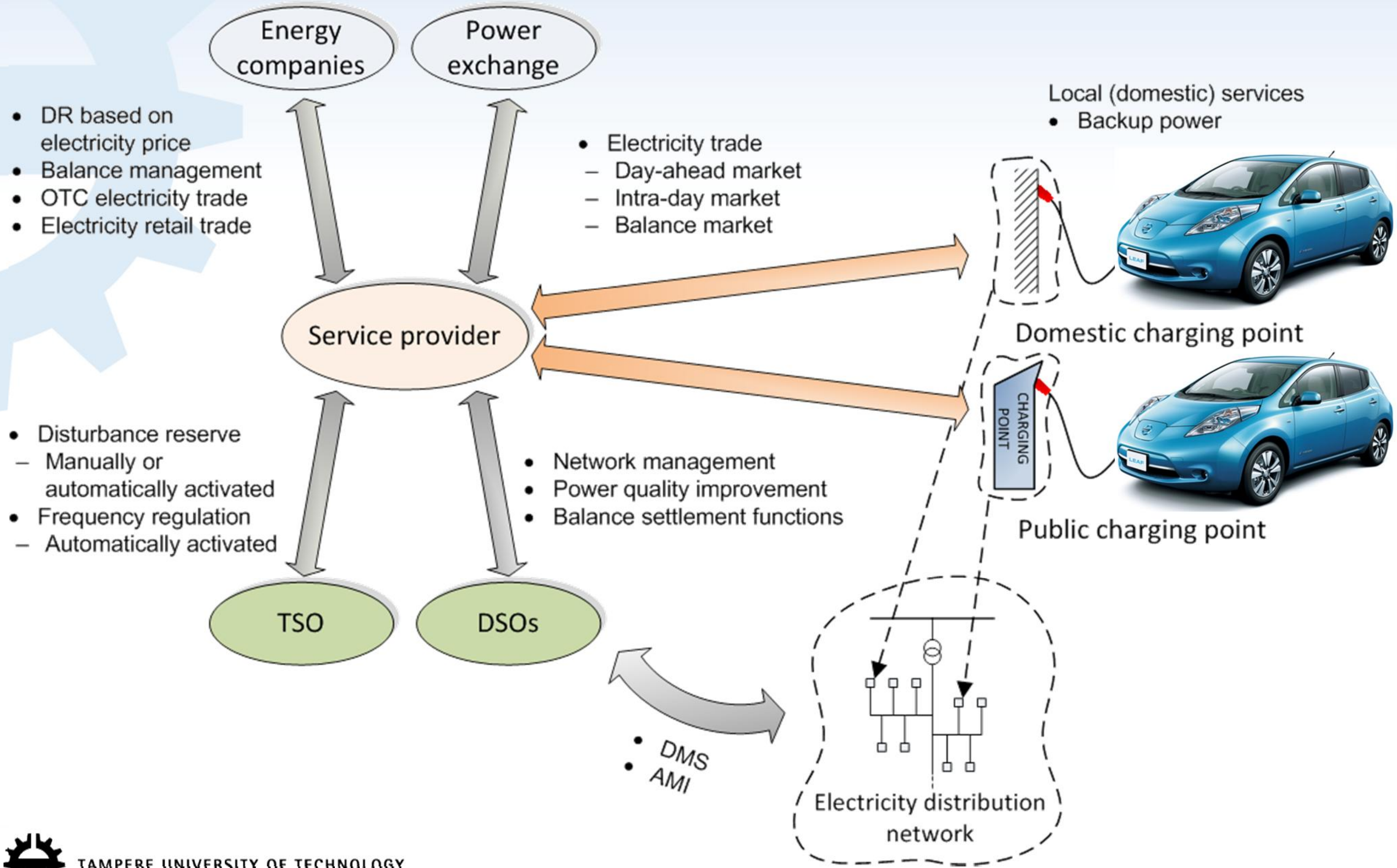


EV as a controllable load or energy storage

Possible use of electric vehicles as resources of Smart Grids

Actor	Use
Energy retailers	• Electricity trade optimization • Balance management • Balancing market operation
Distribution network operators	• Network management (long term planning and real time operation)
Transmission system operator	• Disturbance reserves (manually or automatically activated) • Frequency regulation
Individual electricity consumer	• Backup power • Peak load management • Energy cost optimization • Power quality improvement

Role of service provider in intelligent charging



Intelligent charging / frequency controlled charging

Älykäs latausjärjestelmä

- taajuus- ja/tai jänniteohjatun lataustehon ohjaus
- muu ohjaus

49.85 Hz?
203.5 V?

Frequency value

0.01 Hz accuracy

Fast sampling

Output control

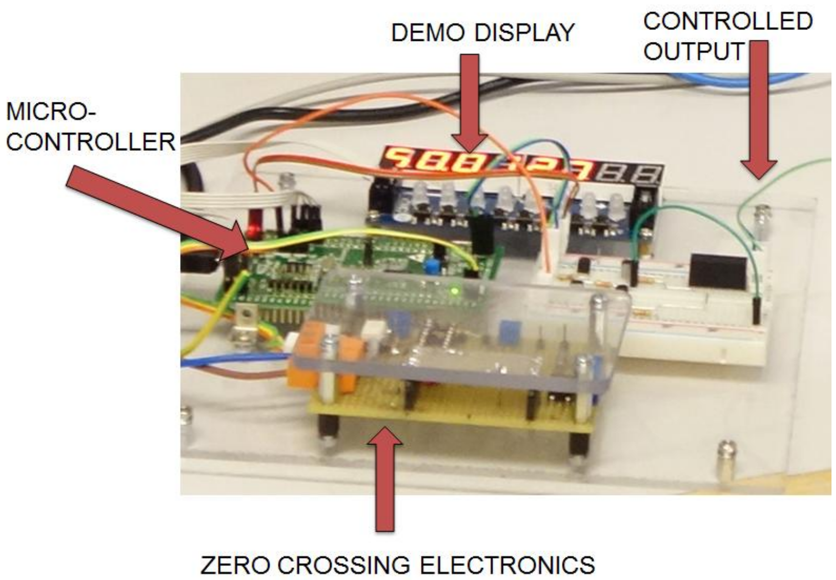
PWM signal adjustment

Charge current limitation

Logging and reporting

Logging past events and submitting information

Status of available reserve?



Electric vehicle charging stations as aggregated frequency containment reserves (FCR)

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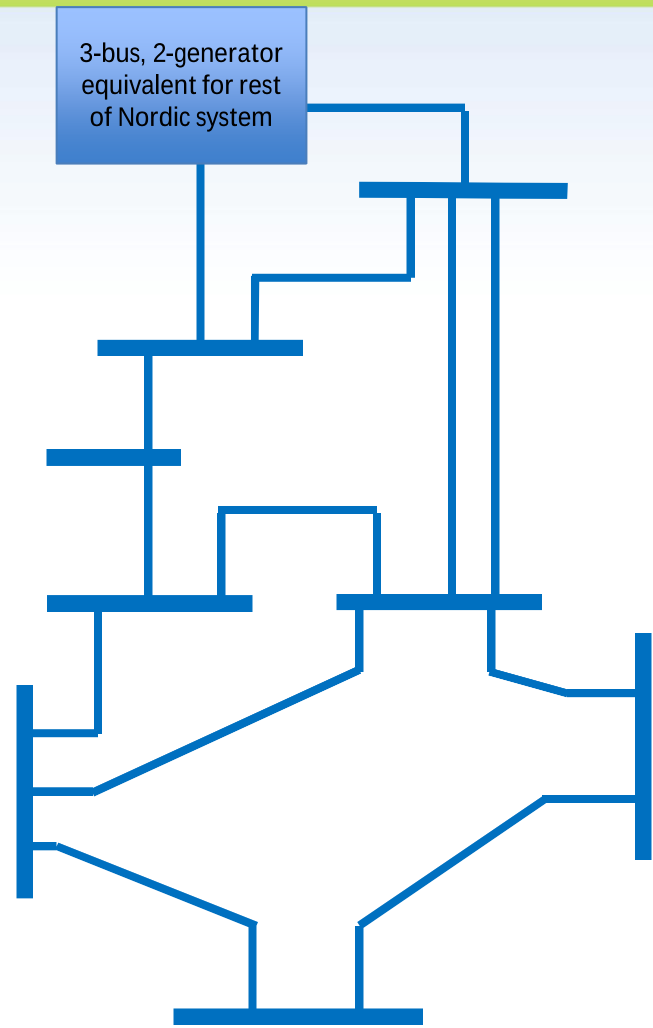
Introduction

- Electric vehicles as aggregated FCR
  - objective is to find out the impacts
    - under disturbances FCR-D,
    - under normal conditions FCR-N
- PSCAD is utilized for the simulations
- Power system utilized consists of three voltage levels
  - a simplified equivalent of the transmission grid (HV) for frequency phenomena studies (source Fingrid)
  - distribution system consisting of MV and LV equivalents from Tampere (source Tampereen Sähkölaitos)
    - the distribution model is connected to the main grid via HV/MV
    - charging stations are on the LV-side

Finnish grid equivalent

- Hihgly simplified equivalent model reflects the structure of Finnish main grid and it consists of 8 nodes which define the 400 kV transmission system
  - generation and loads are connected to the 400 kV nodes via HV/MV transformers
  - the model is feasible for frequency phenomena studies

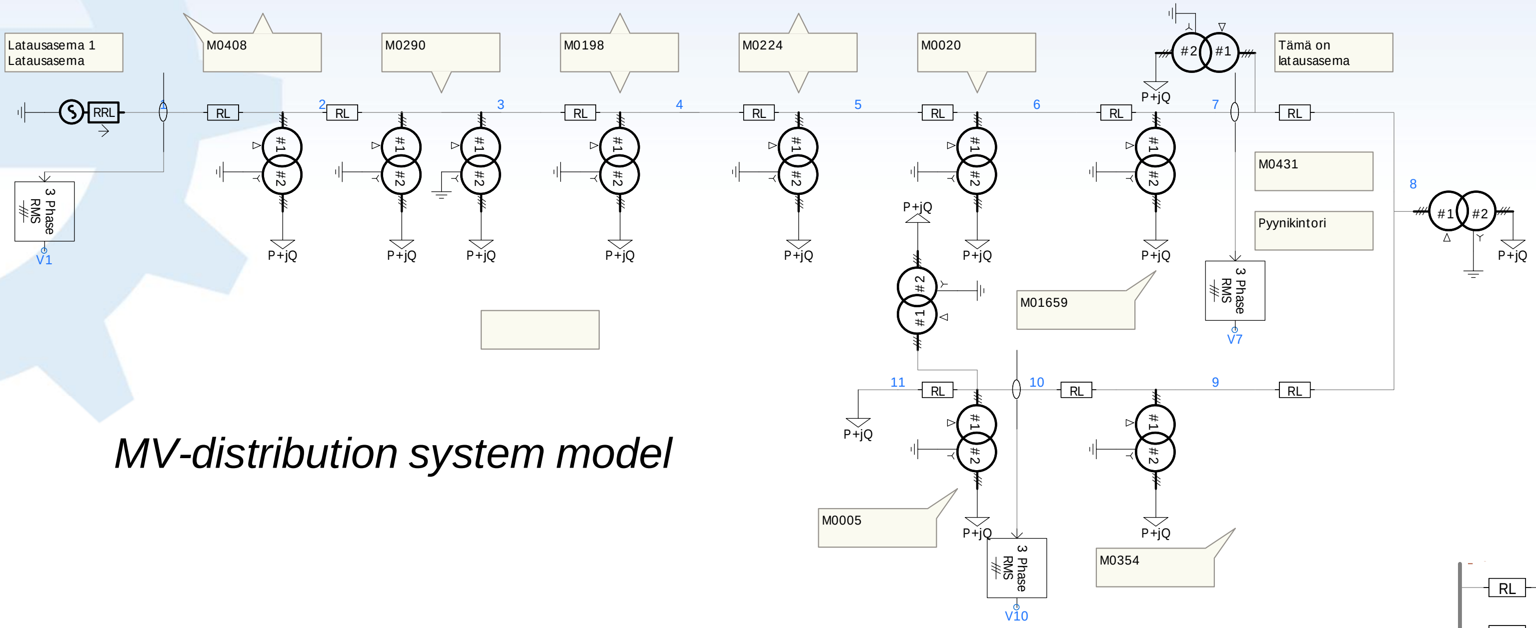
- The effect of the rest of the Nordic power system on frequency response is modelled via two equivalent dynamic generators
  - the two equivalents emulate on general level the effect of the inertia and the frequency reserves in other Nordic countries



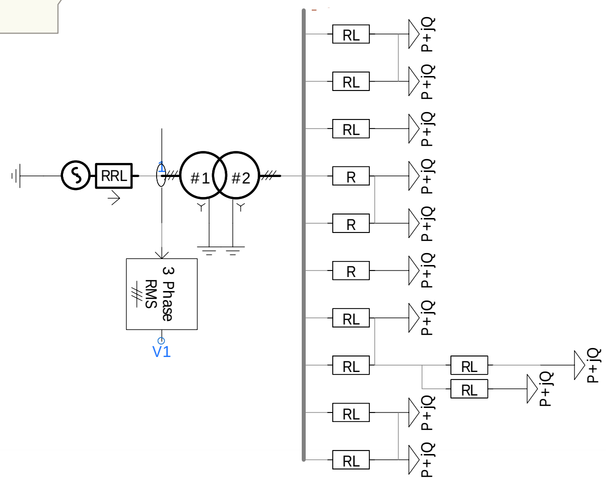
Finnish grid equivalent

Distribution system (source Tampereen Sähkölaitos)

10 to 20 nodes in each MV / LV -model



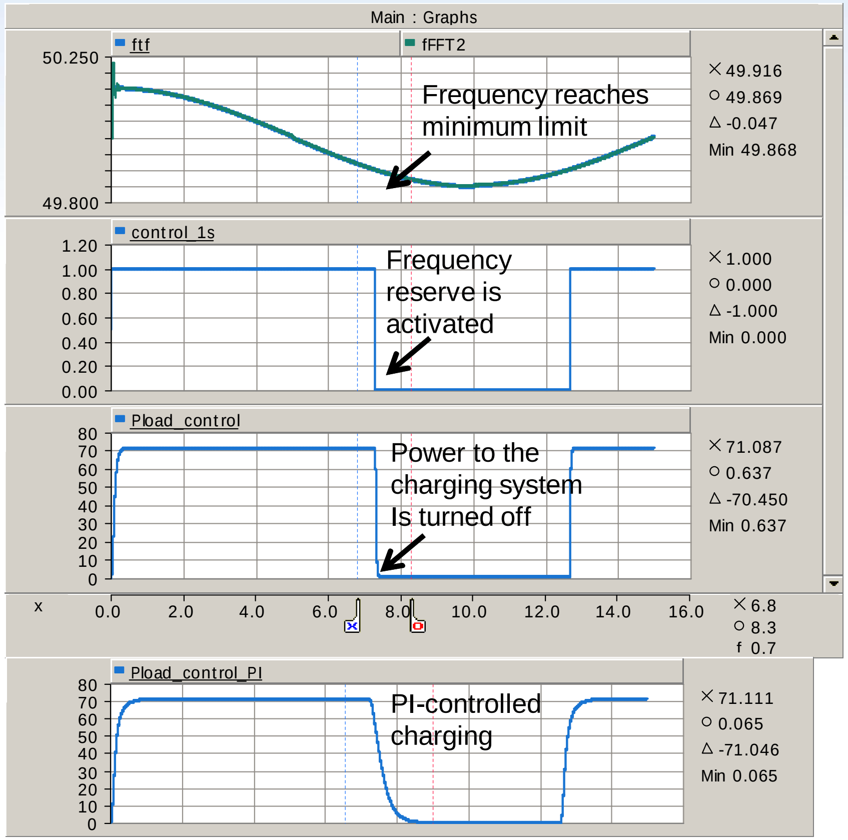
MV-distribution system model



LV-distribution system model

Electric vehicles as FCR

- Frequency limits set by the Grid Code
  - Normal operation
    - f = 49,9 …50,1 Hz
    - no action taken
  - Activation of FCR
    - frequency is outside the normal operation limits
- Electric vehicles as FCR
  - under disturbances and normal conditions
    - activation of reserves outside the normal operation frequency limits
    - utilizing the charger models available (AC/DC/(DC))
- Other reserve loads and reserve power machines also utilized

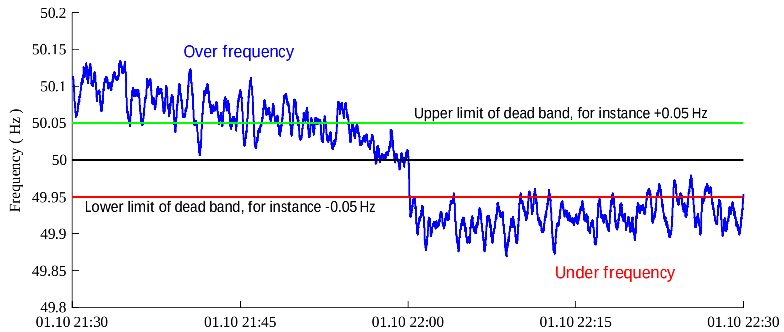


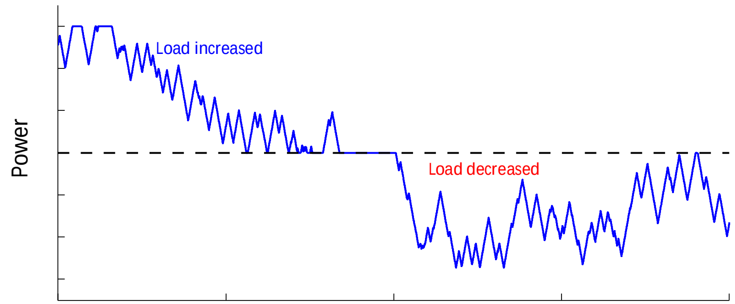
Electric vehicles as FCR

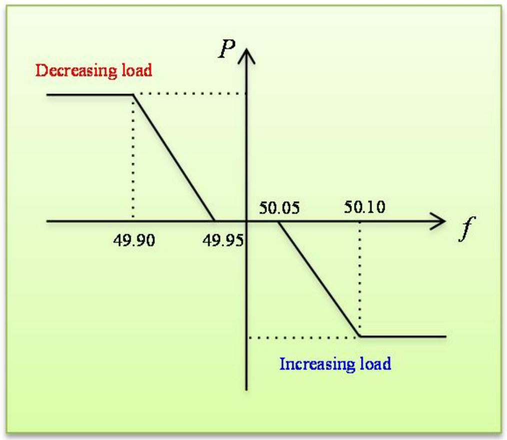
LUT, eCharge, Frequency control

- **Overall target:**
  - Developing simulation models related to frequency control in smart grid environment (and demonstrations)

- **Current status:**
  - Frequency control developed, implemented and tested in Green Campus environment
  - Possbility to demonstrate frequency controlled charging with commercial products (charging poles and EV)







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Smart charging

- Latauksen ohjaus puhtaasti kaupallisia tuotteita ja olemassa olevaa infraa hyödyntäen
- Kaupallinen sähköauto – kaupallinen lataustolppa – tietoliikennerajapinnat yleisesti käytettyjen standardien mukaan

V2G

- Tekninen demo
- Modifioitu Plug-in hybridi (Prius)
- Ei standardi rapapintoja, kommunikaation rauta (auto - tolppa) noudattaa jokseenkin uuden päivittyvän latausstandardin mukaista rakennetta

LUT GREEN CAMPUS DEMONSTRATIONS
Frequency control, controllable charging

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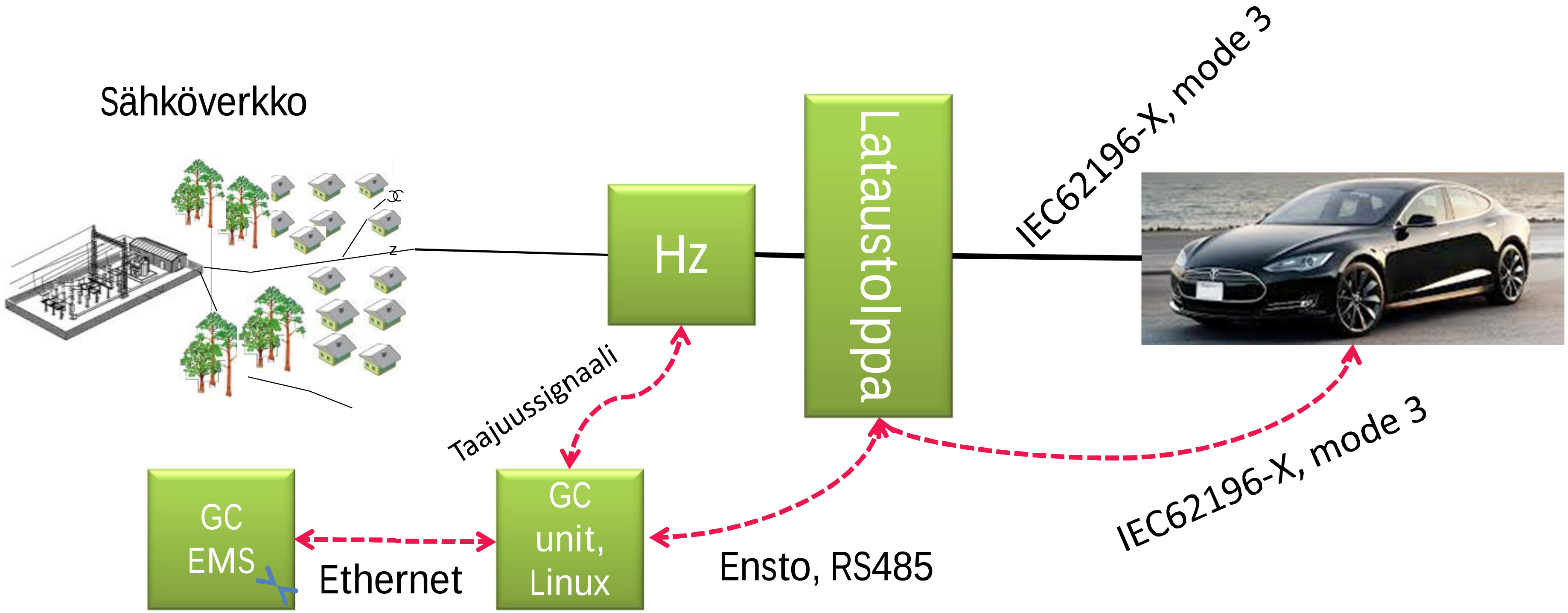

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Frequency control, V2G

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