Universidade do Porto
FEUP Faculdade de Engenharia

INESCPORTO
INSTITUTO DE ENGENHARIA DE SISTEMAS E COMPUTADORES DO PORTO
LABORATÓRIO ASSOCIADO

Campus da FEUP
Rua Dr. Roberto Frias, 378
4200 - 465 Porto
Portugal

T +351 222 094 000
F +351 222 094 050

jpl@fe.up.pt

IEEE Boston Section –

Demystifying the Smart Grid

Boston– November 2009

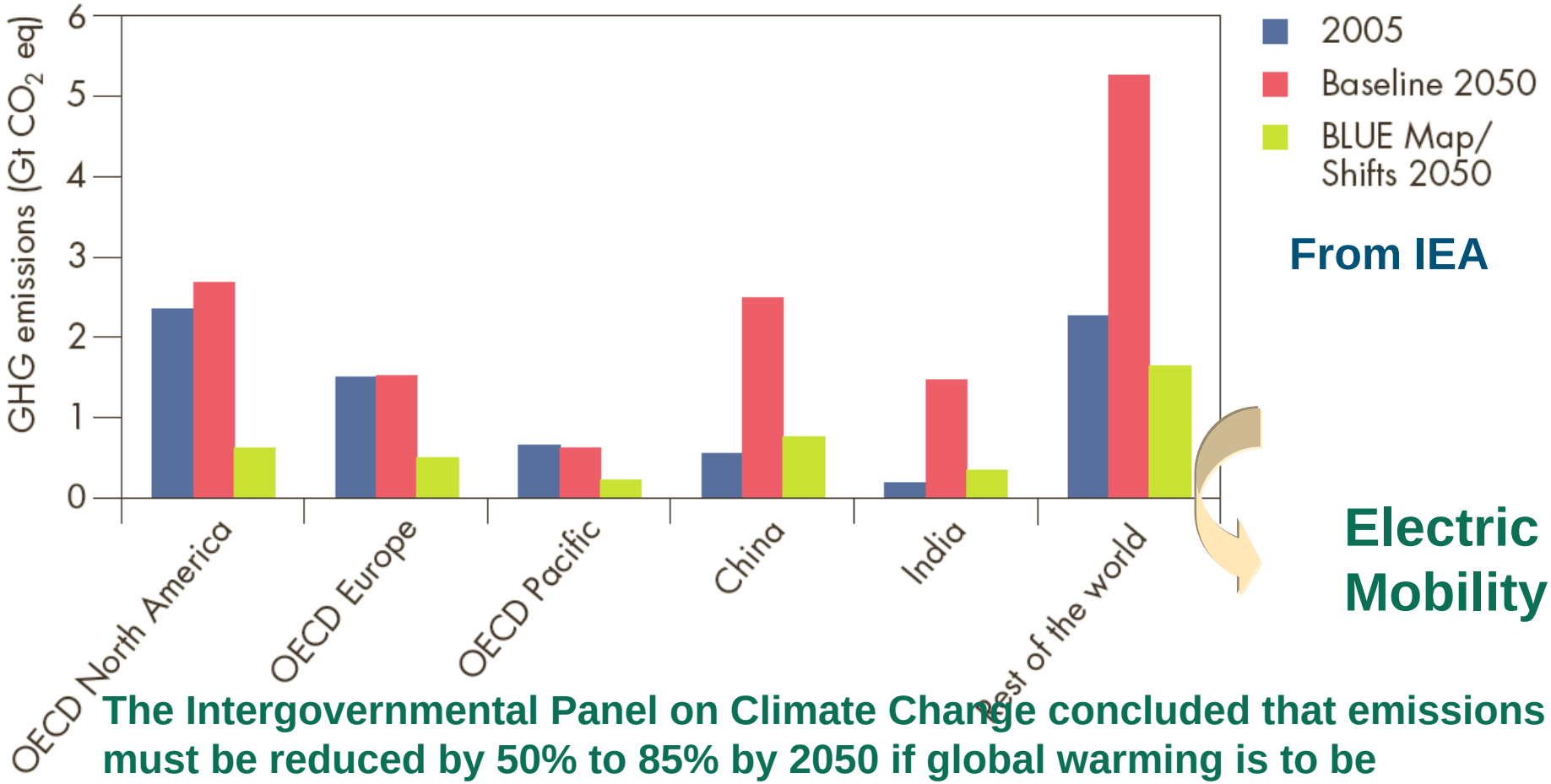
Electric Vehicle Grid Integration

J. A. Peças Lopes

(jpl@fe.up.pt)

Introduction: The need to make the mobility shift

Transport GHG emissions by region and scenario, 2005 and 2050



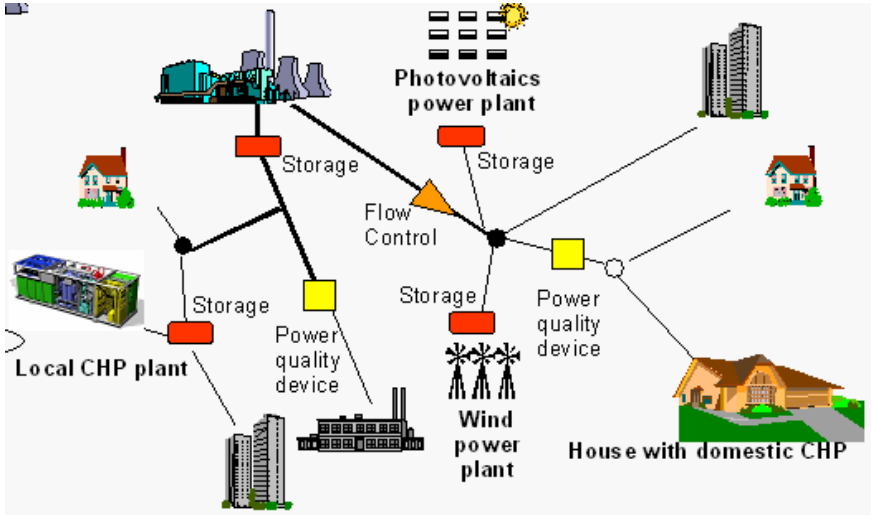
From IEA

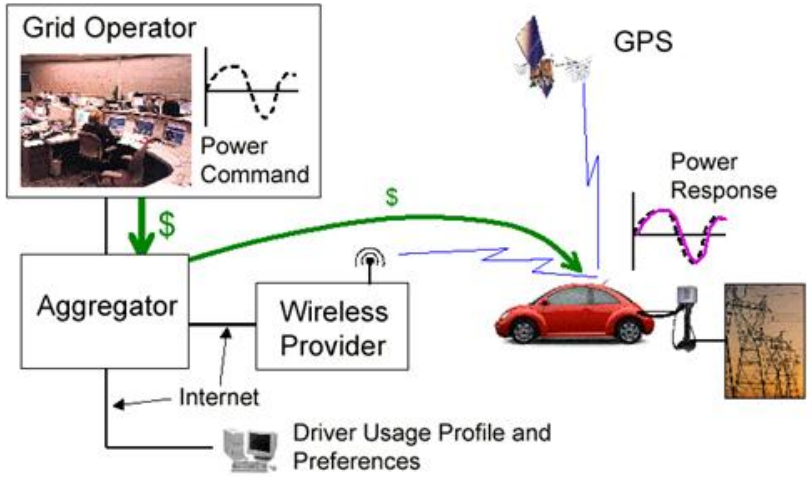
Electric Mobility

The Intergovernmental Panel on Climate Change concluded that emissions must be reduced by 50% to 85% by 2050 if global warming is to be confined to between 2°C and 2.4°C

Introduction – New chalanges for the electric power industry

- A new revolution is on the way – PHEV and the V2G concept:
  - These electric vehicles will require the use of electric batteries with capacity to store energy, PHEV will either be:
    - Controllable charges that absorb energy and
    - Storage devices that may provide electricity to grid.





Types of EV available and business models

Grid connected EV Types:

- Plug-in Hybrid EV → use a small battery and a generator combined with an ICE.

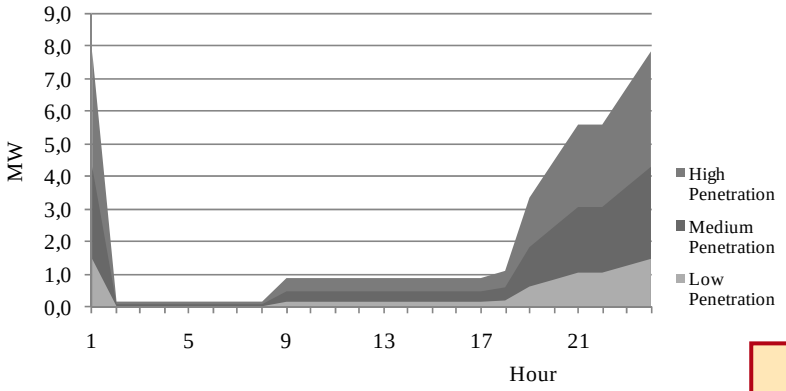
- Battery EV → powered only by electricity, what requires a large battery pack.

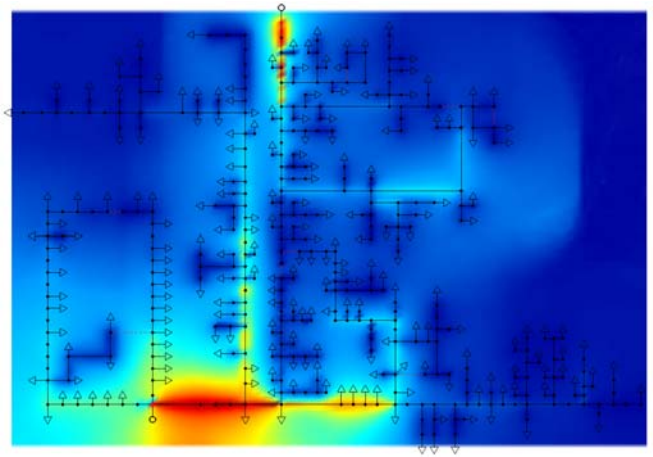
Business Models:

- Slow charging;
- Fast charging stations
- Battery replacement

Integration of PHEV in theelectric power system

- Problems
  - Peak load will increase requiring more conventional power plants
  - **Network congestion problems** and **large voltage drops** (also **unbalacing in LV grids**) for dumb charging approaches





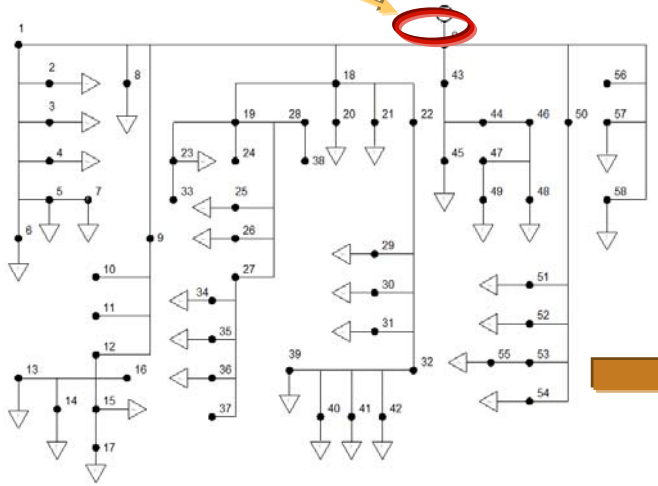
  - Smart charging is required using dynamic tariff schemes and additional control procedures where the electronic interface will respond to voltage and frequency changes at the battery grid connection point.

Definition of an evaluation procedure to define PHEV integration limits

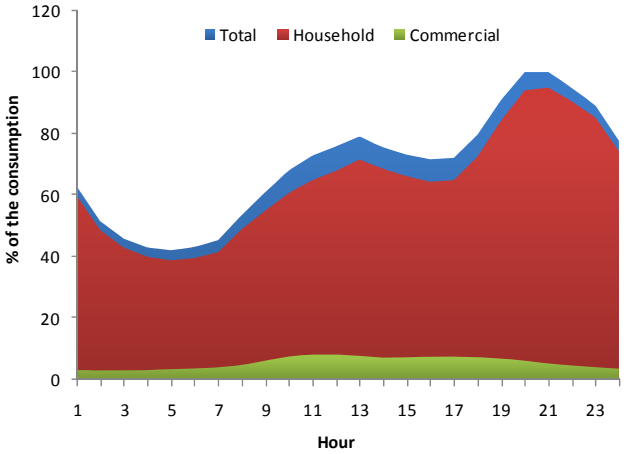
Analysis of LV and MV grids

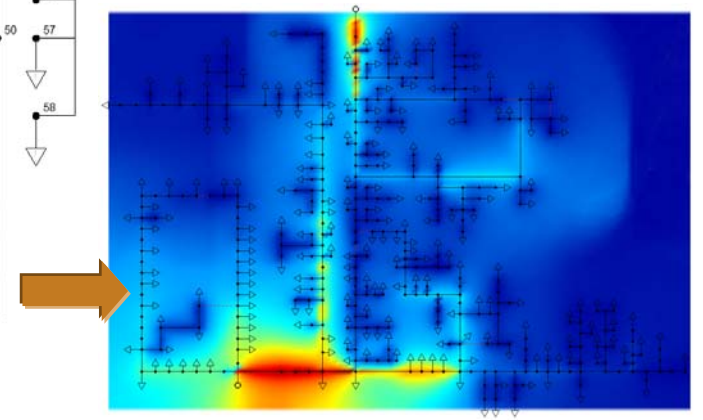
An example

- Residential LV network (400 V)
- Feeding point voltage → 1 p.u.
- Feeder capacity → 630 kW
- 250 households
- 9.2 MWh/day
- 550 kW peak load



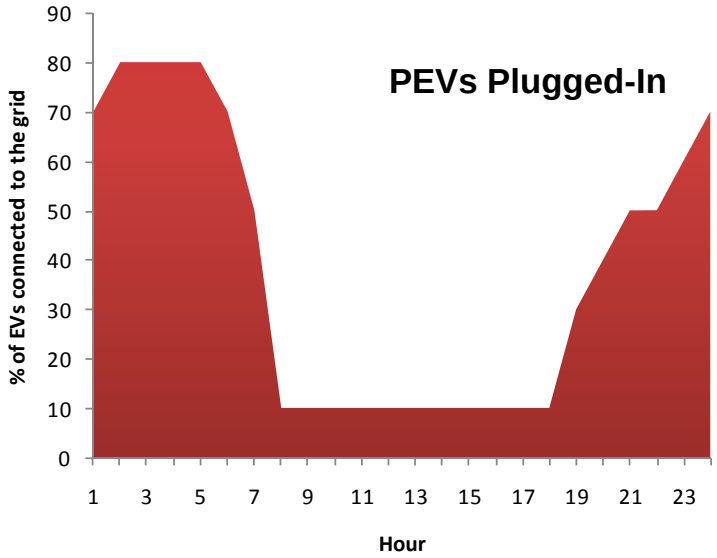
Grid Load Diagram (no PEVs)





Dealing with the Electric Vehicles

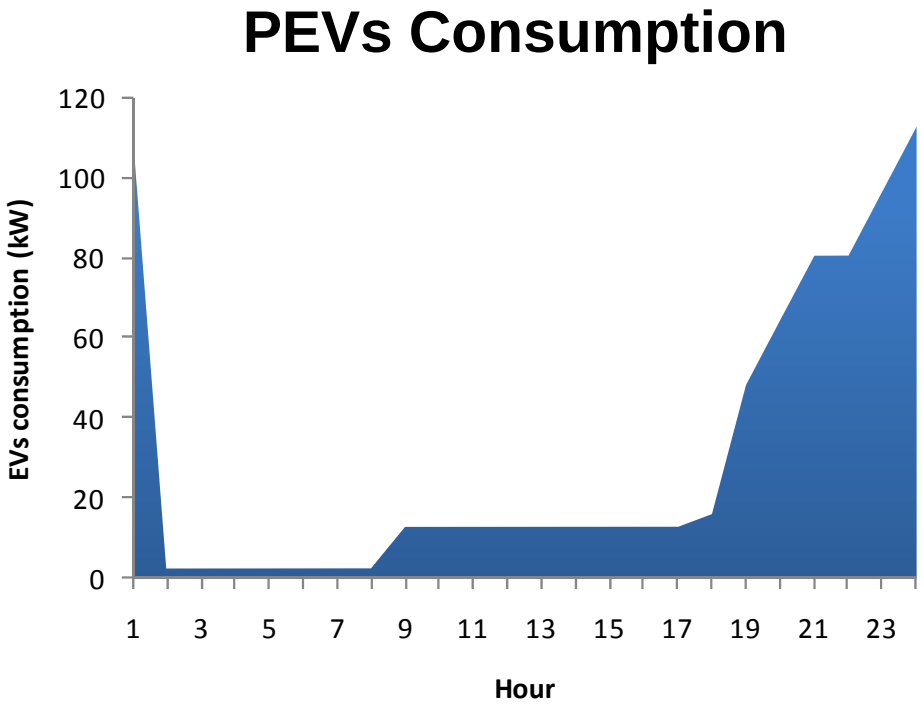
- 375 vehicles
- Annual mileage → 12800 km
- Daily mileage → 65 km
- EVs charging time → 4h
- 3 types of EVs:
  - Large PEV → 6 kW
  - Medium PEV → 3 kW
  - Plug-in Hybrid EV → 1.5 kW



“Dumb charging” results

Allowable PEVs integration without grid reinforcements

11%

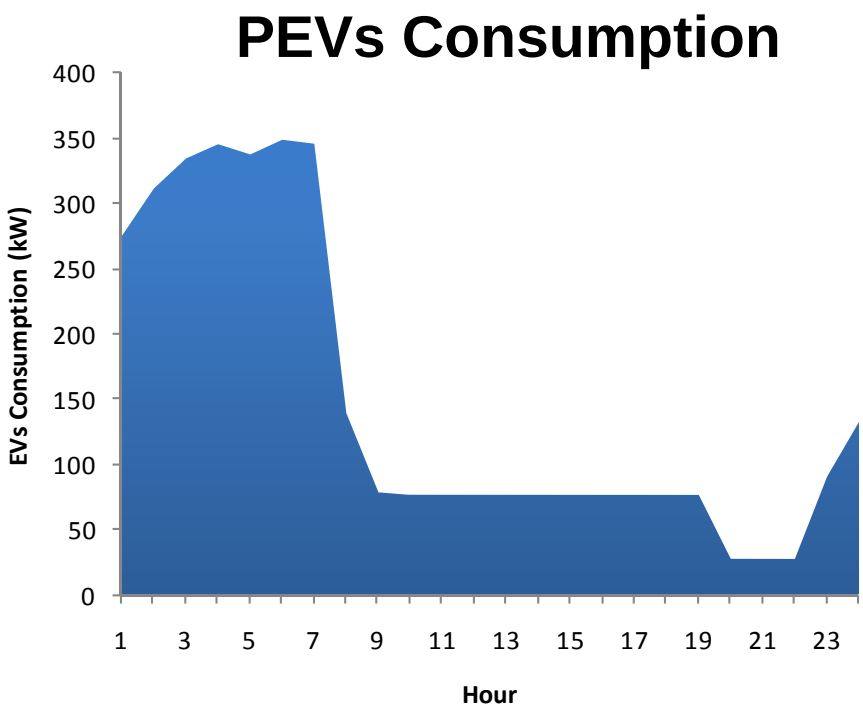


“Smart charging” results

Optimizing the charging procedure, taking into account grid restrictions to be managed by system operators

Allowable PEVs integration without grid reinforcements

61%

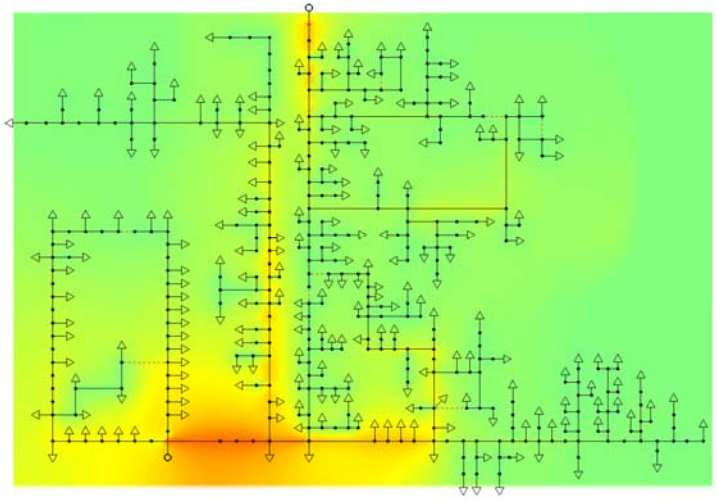


Results regarding maximum allowable EVs integration in a MV grid

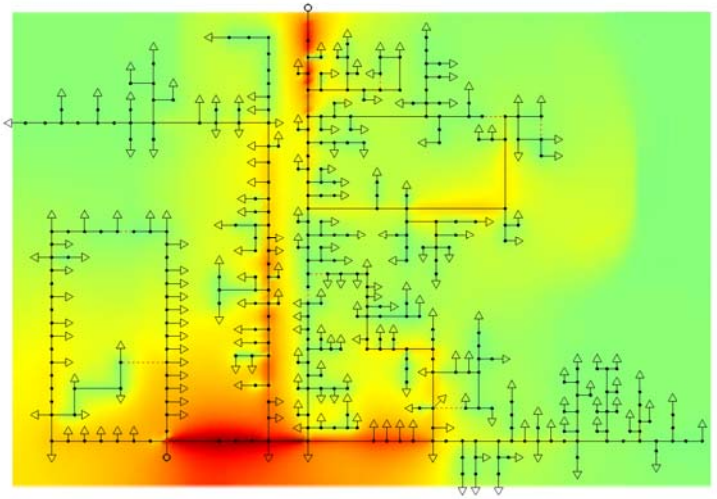
- **Dumb charging approach - 10%** allowable EVs integration
- **Dual tariff policy (present rules)– 14%** allowable EVs integration (considering that 25% of the EVs only charge during the cheaper period – valley hours)
- **Smart charging strategy – 52%** allowable EVs integration → resolution of an optimization problem at the level of a local aggregator.

Results: branches' congestion levels overview (peak hour)

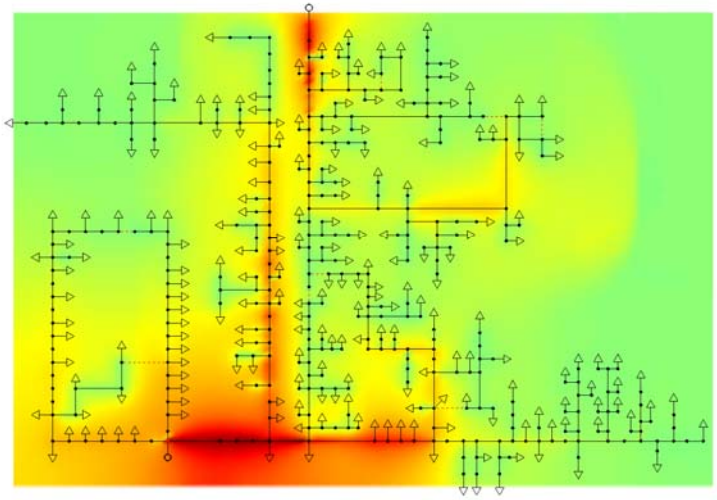
No EVs



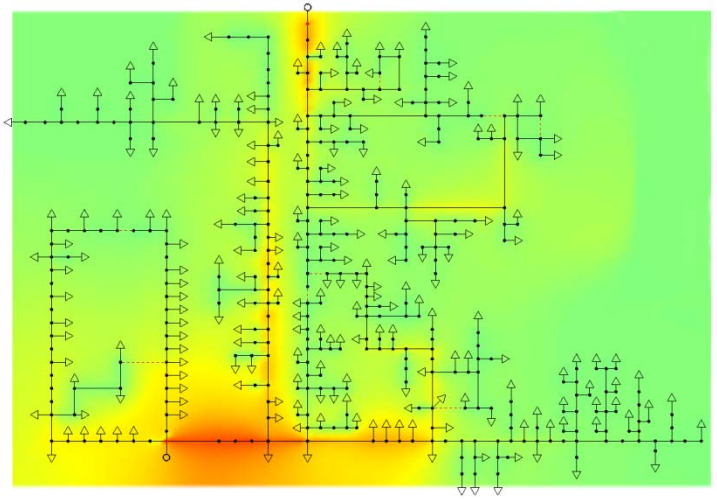
Dumb charging – 52% EVs



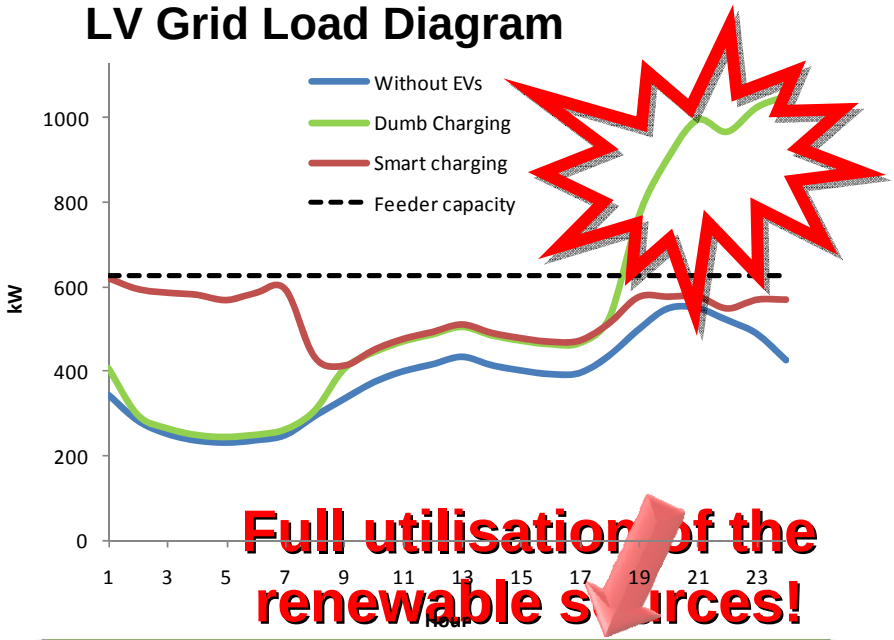
Dual tariff – 52% EVs



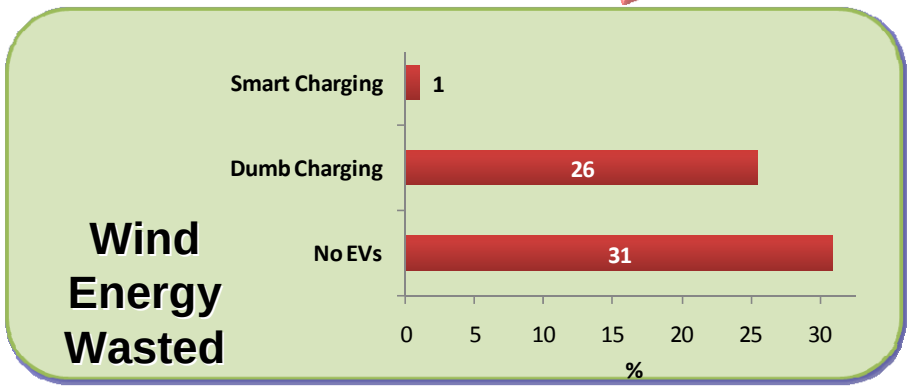
Smart charging – 52% EVs

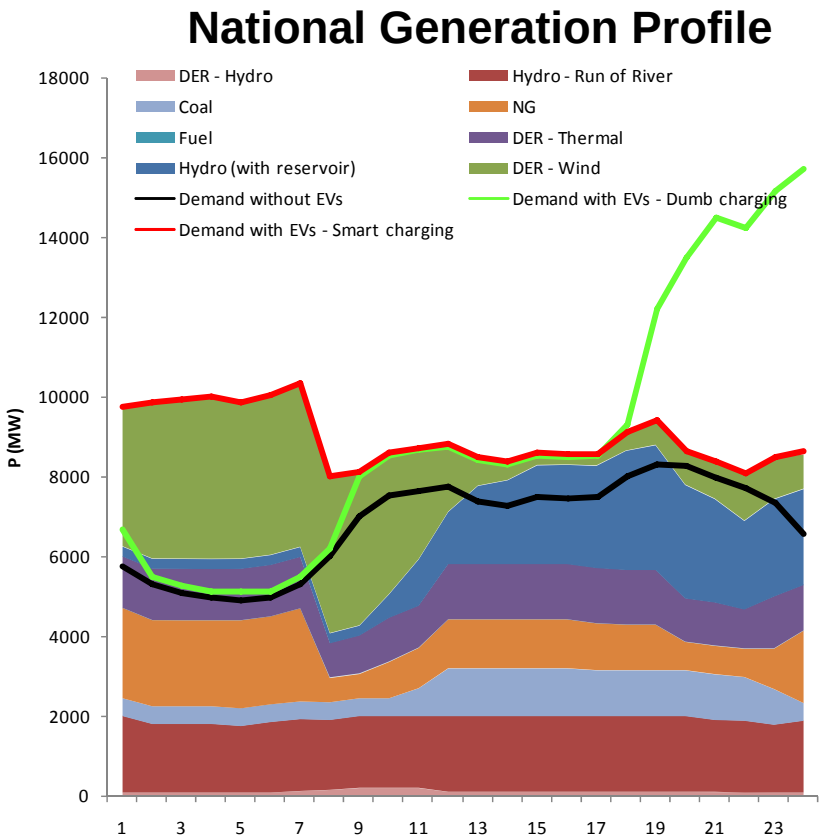


Demand change due to 61% of PEVs



Full utilisation of the renewable sources!

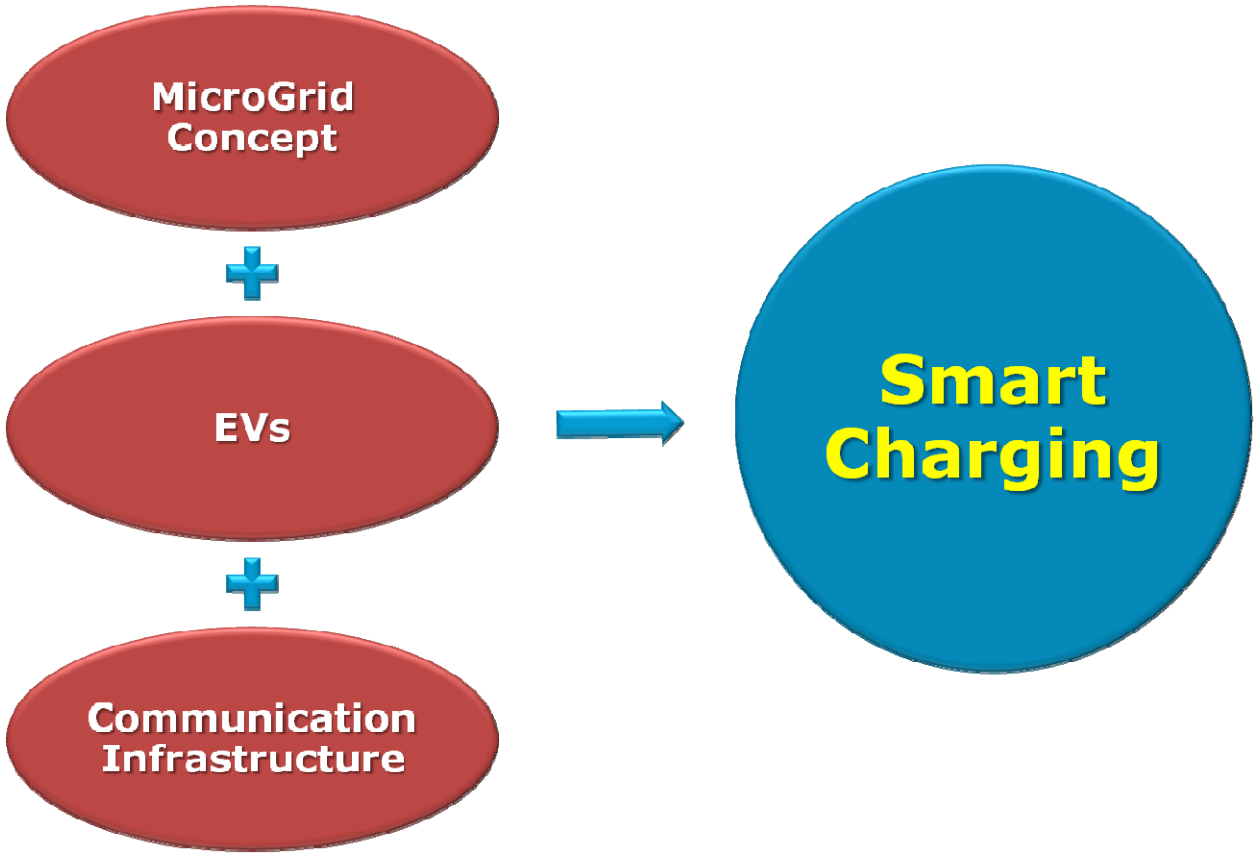




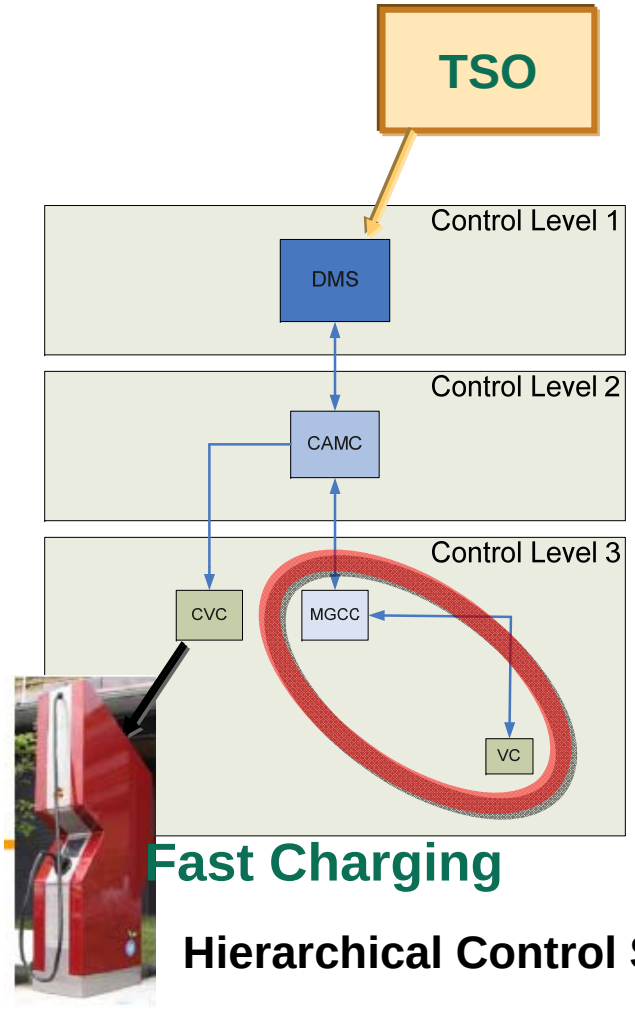
No reinforcements in the generation system are required and the existing Grid infrastructure will be caple of handling with the problem

EV Smart Charging

EV Smart charging means the PEV battery charging in the *right place in the right moment*

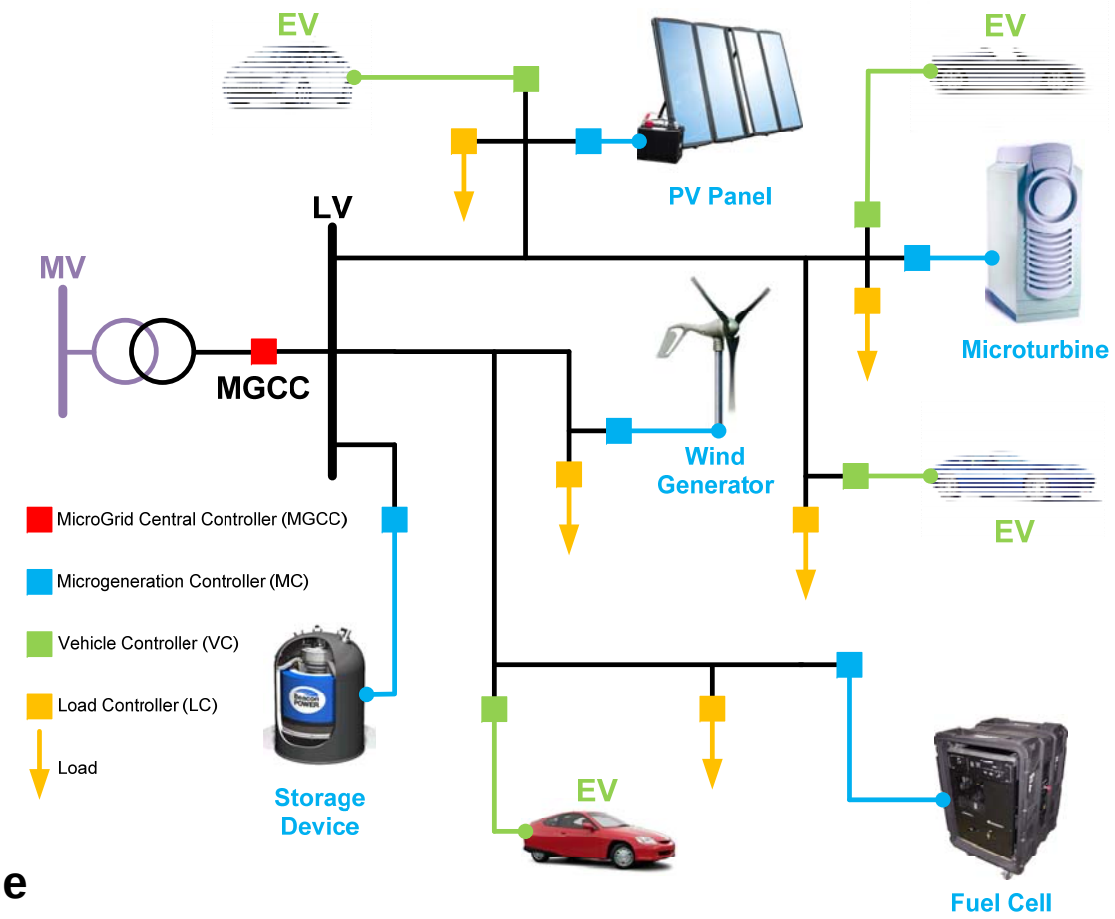


Microgrids and EV + Integrated control infrastructure

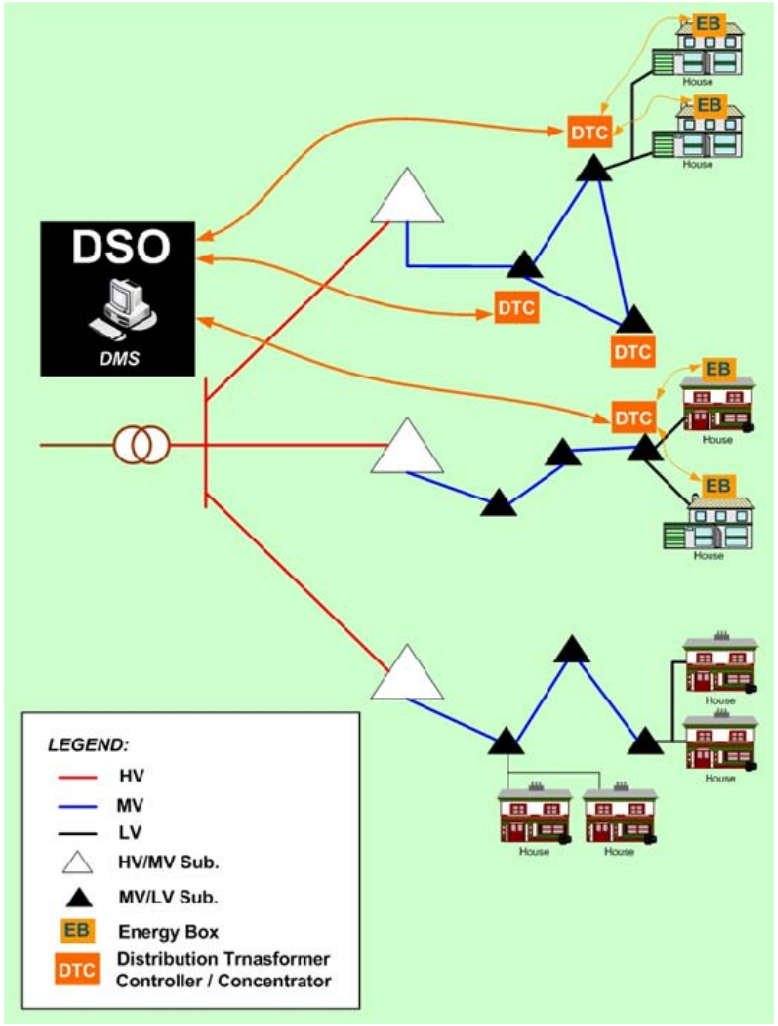


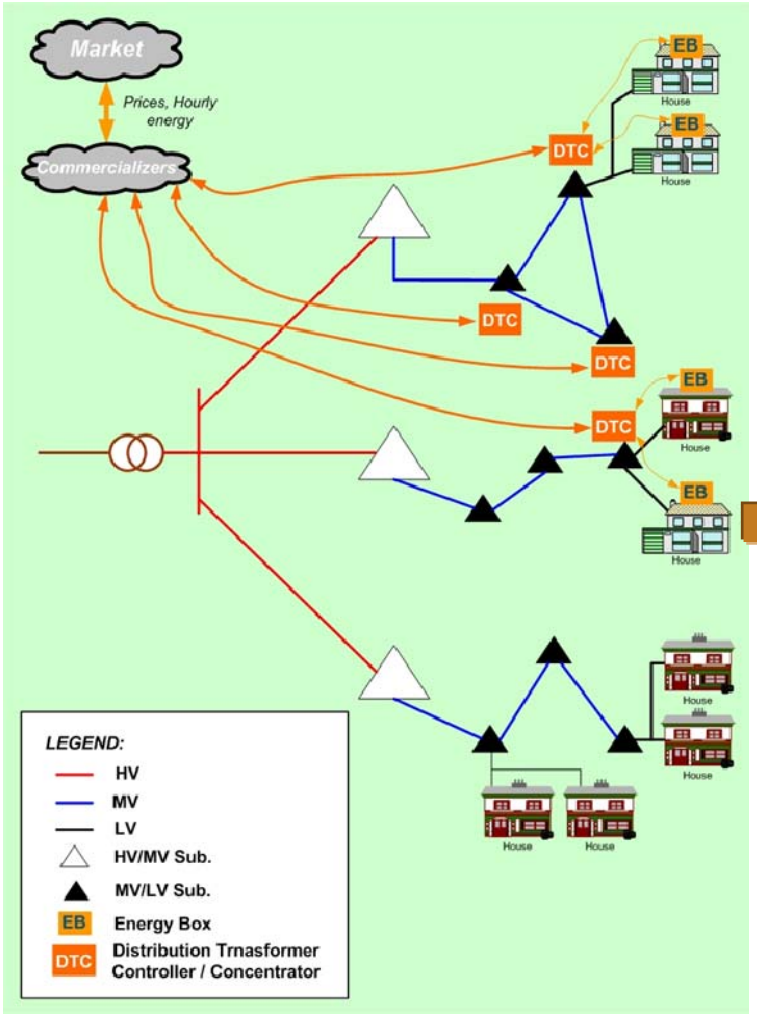
Fast Charging

Hierarchical Control Scheme



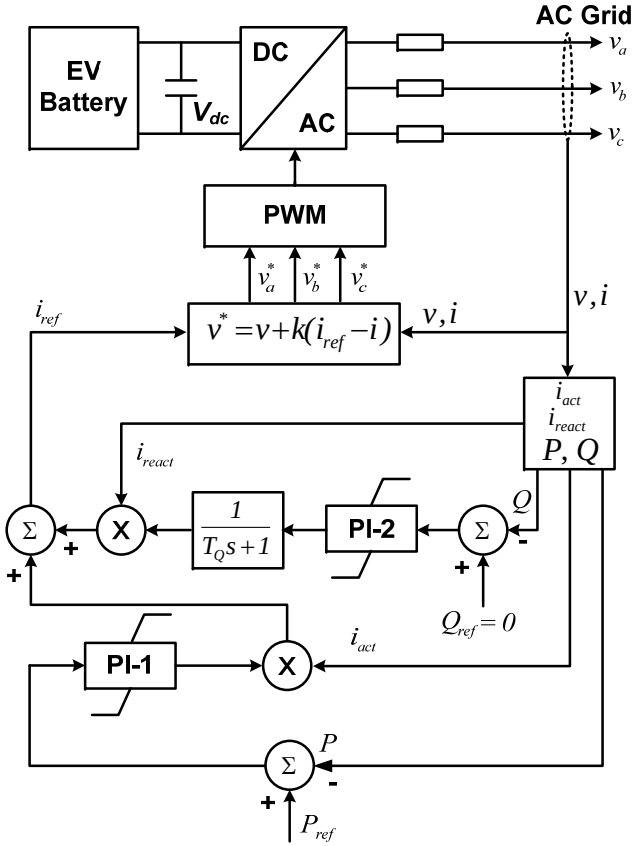
SmartMetering infrastructure helps to technically manage the microgrid





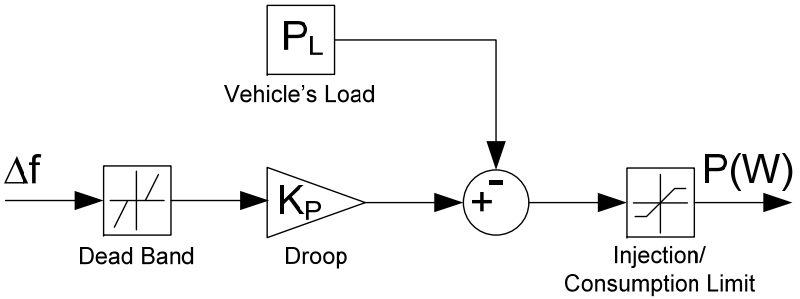
ICTs

EV electronic grid interface modeling for islanded systems



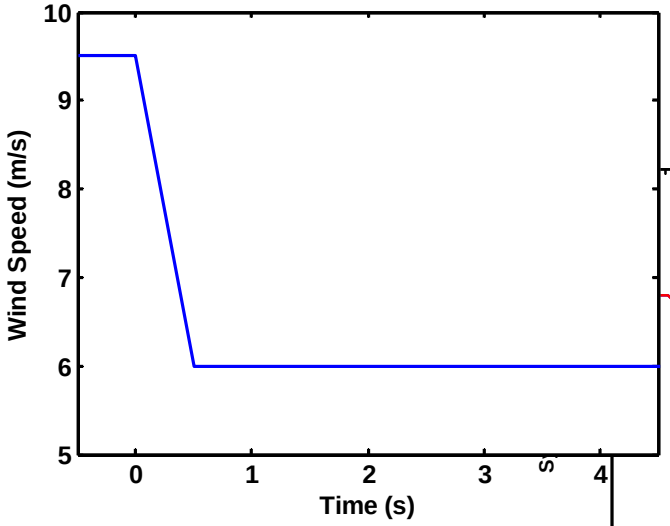
PQ inverter control system

- A PQ inverter control logic was adopted
- Set-points for active power controlled by a proportional gain that reacts to frequency deviations



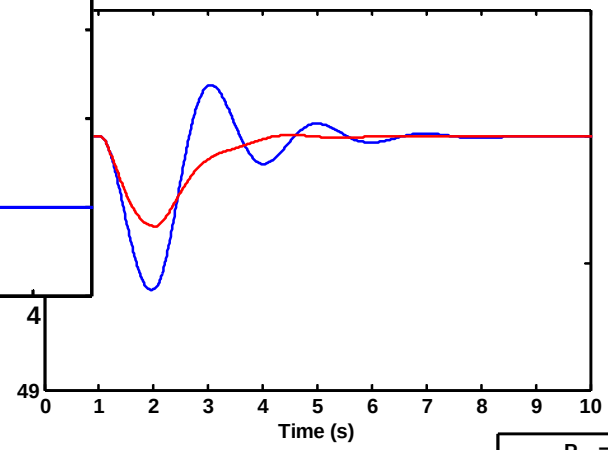
Control loop for EV active power set-point

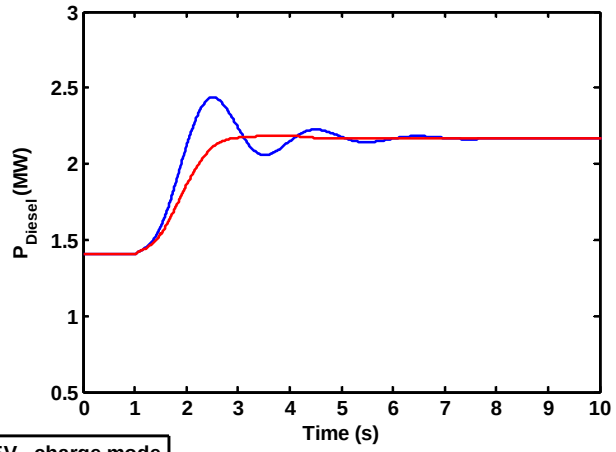
Results - islanded systems

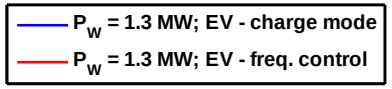


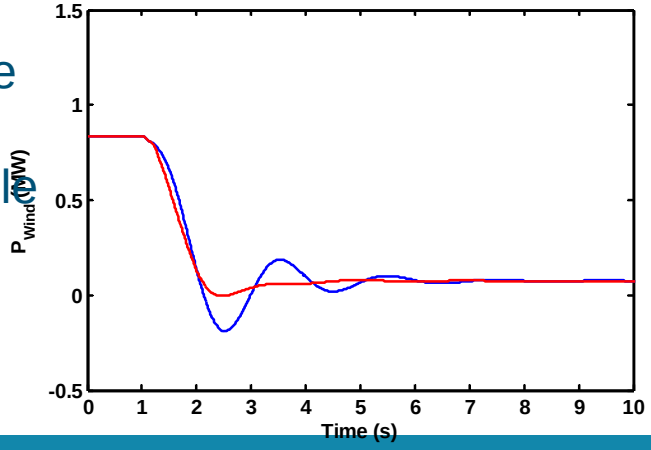
Sudden wind power change

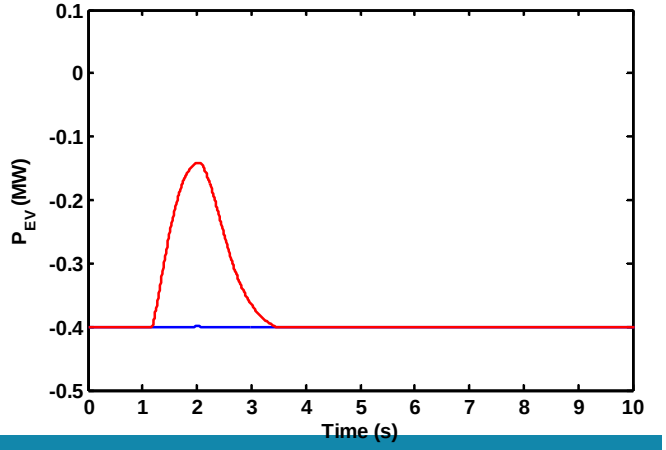
(a limiting factor to the integration of Intermittent Renewable Energy Sources)











Conclusions

- The future integration of PEV will bring new challenges and opportunities to the electric power system industry;
- Future large scale deployment of PEV on the grid will only be possible with a communication infrastructure on the field → **smart metering can also be used for the this purpose**

- The electric power industry is facing a tremendous opportunity that should be profited to bring additional technical benefits and economic revenues