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Smart Grids and Mobility

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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.
Smart Players

The success of the shift requires:

- Smart Generation
- Smart Grid
- Smart Consumption
- Smart Storage
- Smart Regulation
A new revolution is on the way: PHEV deployment

- **PHEV penetration:**
  - Unidirectional power flow to charge batteries
  - 4.6kW LV single-phase
  - highly distributed

**OR**

- 20kWh
- 12 - 24kW three-phase

**AND**

**Battery Charging / Replacement Stations**

- 600kW – 1 MW three-phase
- 10kV, 35A
Integration of PHEV in the grid

- **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.
Analysis of LV and MV grids

An example

- Residential LV network (400 V)
- Feeding point voltage $\rightarrow$ 1 p.u.
- Feeder capacity $\rightarrow$ 630 kW
- 250 households
- 9.2 MWh/day
- 550 kW peak load
Dealing with the Electric Vehicles

- 375 vehicles
- Annual mileage $\rightarrow$ 12800 km
- Daily mileage $\rightarrow$ 35 km
- EVs charging time $\rightarrow$ 4h
- 3 types of EVs:
  - Large PEV $\rightarrow$ 6 kW
  - Medium PEV $\rightarrow$ 3 kW
  - Plug-in Hybrid EV $\rightarrow$ 1.5 kW
“Dumb charging” results

Allowable PEVs integration without grid reinforcements

11%

PEVs Consumption

EV's consumption (kW)

Hour
“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%

PEVs Consumption

Hour
Demand change due to **61%** of PEVs

Full utilisation of the renewable sources!

LV Grid Load Diagram

No reinforcements in the generation system are required and the existing Grid infrastructure will be capable of handling with the problem.
Results: Environmental Impacts

Daily CO₂ Emissions

- Power system emissions (including: extraction and processing; raw material transport; and electricity generation)
- Light vehicles emissions (well-to-wheel)

*Smart charging
1. A typical Portuguese MV grid has been characterized in terms of load:

   ![Diagram of a MV grid]

2. Based in mobility statistical data for Portugal, EVs electricity demand throughout the day was calculated for all charging approaches:

   ![Graph showing electricity demand]

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Results regarding the maximum allowable EVs integration

- **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
  (considering that 50% of EVs‘ owners adhered to the smart charging system) → 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
EV Smart charging means the PEV battery charging in the **right place in the right moment**
Microgrids and EV

- Microgrids can increase resilience and increase the acceptance of RES due to a large presence of distributed storage devices.
Hierarchical Control Scheme
SmartMetering infrastructure helps to technically manage the microgrid

LEGEND:
- **HV**
- **MV**
- **LV**
- **HV/MV Sub.**
- **MV/LV Sub.**
- **EB**
- **DTC**

**ICTs**
Participation in frequency regulation → Microgrid islanding operation – development of the V2G concept

With proper grid electronic interfaces control

(a) Frequency Regulation

(b) Voltage Regulation

(a) Without V2G Devices

(b) V2G Devices with Fixed Charging Rate

(c) V2G Devices with Control: $f_0 = 49.5$ [Hz]

(d) V2G Devices with Control: $f_0 = 49.9$ [Hz]
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 → the smart metering

• New technological opportunity niches are appearing

• SmartMetering projects should capitalise on these new opportunities → Pilot test sites are needed

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

• Commitment in Applied Research will be the key issue for the success → Development of V2G concepts need further in depth research

• Advanced training is also required