Impact of E-Mobility on the Electrical Grid

Outlook for future Integration Strategies
Electromobility and Renewable Energy Resources in Germany: Political Framework

Technological aims for Germany:
- **2020:** 1 Million Electric Vehicles (EV)
- **2030:** 5 Million EV
- **2030:** 30% of electric demand generated by renewable resources

Electromobility: key element for future energy system, with a high rate of renewable energy sources

source: handelsblatt.com
Effects of increasing Renewable Generation

Example: wind power infeed in northern Germany

**Today's Electric Energy System:**

"Generation follows electrical Demand"

- conventional power plants provide power when needed

**Tomorrow: Increasing Fluctuating Renewable Generation:**

- Power Generation not depending on Demand

Challenge for today's energy system:

1) Adapt demand to current generation situation, flexibilisation of demand
2) Electrical energy storage
Battery Storage solutions: Central Approach

Northern Japan:
34 MW, 245 MWh unit for wind stabilization

Source: www.electricitystorage.org
Battery Storage Solutions: Distributed Approach

40 million cars in Germany:

Assumption: 10 % EV = 4 million cars
- Power: 3 kW average household plug
- Battery capacity: 20 kWh battery (100km)

Simplified mathematic experiment:
- Power = 3kW x 4 mio cars = 12 GW (~10 nuclear power plants)
- Energy = 20kWh x 4 mio cars = 80 GWh (1 nuclear power plant running 3 days)
Uncontrolled Charging of EV

Uncontrolled Charging:
Charging starts when car is plugged-in
Uncontrolled Charging of EV

Simulation:

Distribution Grid:
- suburban german area
- ~100 households

Electric Vehicles:
- 20 Electric Vehicles
- power demand= 10kW
- charging after last trip
- high simultaneity expected in the evening

Conclusions:
- Even a small rate of Electric Vehicles could strongly affect the power demand of a distribution grid.
- Increasing stress of grid equipment expected, overload is possible
Low voltage grid: Load effects

With increasing load demand – decreasing voltage
- voltage no longer within specification
- transformer or line overload
Low voltage grid: Infeed effects

With increasing infeed – increasing voltage
- voltage no longer within specification
- transformer or line overload

Smart distribution grid: Control of loads and generation
Battery Storage: Distributed Approach

Power exchange of EVs with grid is controlled by distribution grid substation (NAS)

Fluctuating renewable power generation is stored in distributed vehicle batteries

EV infeed in case of peak load demand

-> only parked and plugged-in EVs are able to support the electrical grid
Integration Strategies: Simulation

**Strategy:**

1) **Controlled Drive Energy Charging:**
   Controlled EV charging during low power demand

   -> avoiding charge peak loads in the evening

2) **EV<-> Grid Energy Exchange:**
   Using free battery capacities for distributed storage, high renewable energy infeed is stored and used to limit local peak loads

   -> fluctuating renewable generation can be balanced by EV
Integration Strategies: Simulation Tool

Grid Simulation considers:
- dynamical load demand of 100 households

- 20 Electric Vehicles:
  \[ P_{\text{Charge/Infeed}} = 10 \text{ kW} \]
  \[ E_{\text{Battery}} = 20 \text{ kWh} \]

- dynamical driving behavior:
  - typical drive ranges
  - typical departure/arrival times
Integration Strategies: Load Balancing Potential

1. Original grid load curve

2. Drive Energy Charging

3. EV <-> Grid Exchange Charging/Infeed

4. Resulting load curve
Conclusion:

Electric Vehicles form a new class of consumer loads in the distribution grid

- Uncontrolled charging can lead to:
  - increasing peak loads
  - overload of grid structure
  - decreasing grid quality

- Integration of EVs in grid management can:
  - improve grid quality
  - form distributed storage
  - support renewable energy sources