Karlsruhe Institute of Technology

Impact of E-Mobility on the Electrical Grid

Outlook for future Integration Strategies

Institute of Electric Energy Systems and High Voltage Technology

Electromobility and Renewable Energy Resources in Germany: Political Framework

source: handelsblatt.com

Technological aims for Germany:

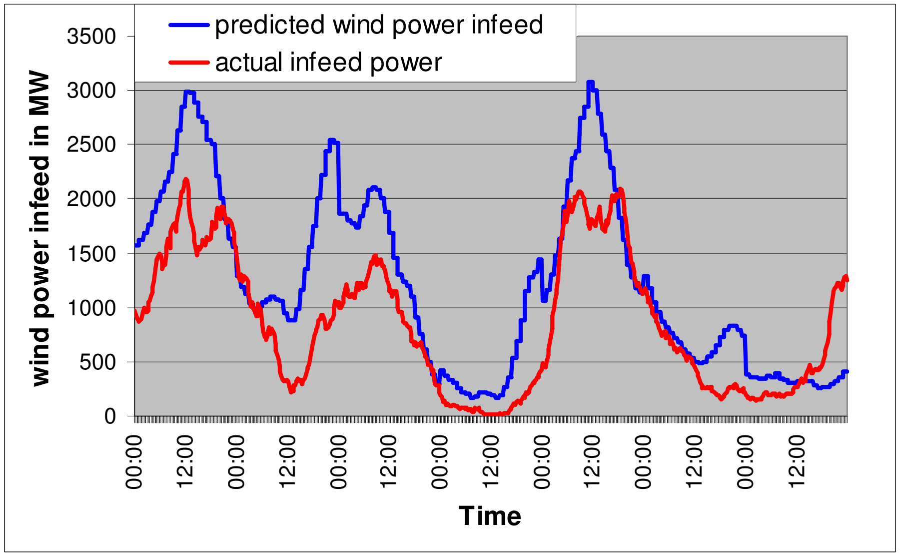
2020: 1 Million Electric Vehicles (EV)

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

Effects of increasing Renewable Generation



Example:
wind power infeed
in northern Germany

Todays 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 todays energy system:

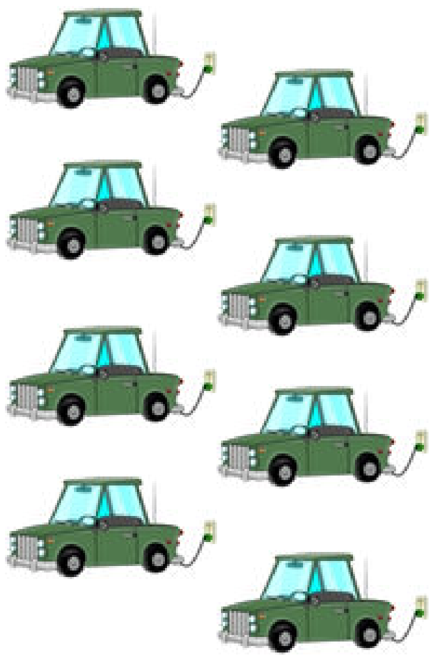
1) Adapt demand to current generation situation, flexiblisation of demand
2) Electrical energy storage

Battery Storage solutions: Central Approach

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

Source: www.electricitystorage.org

Battery Storage Solutions: Distributed Approach



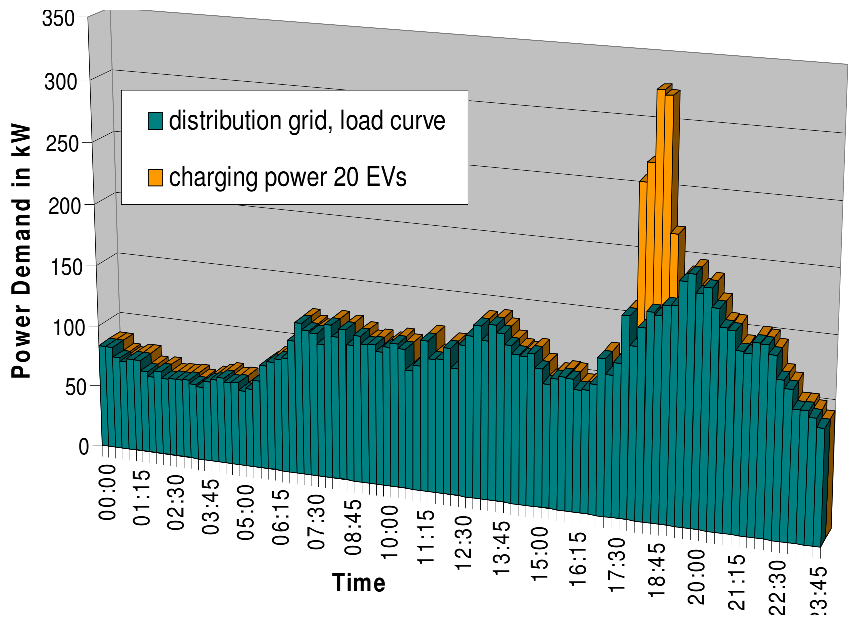
40 million cars in Germany:

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)

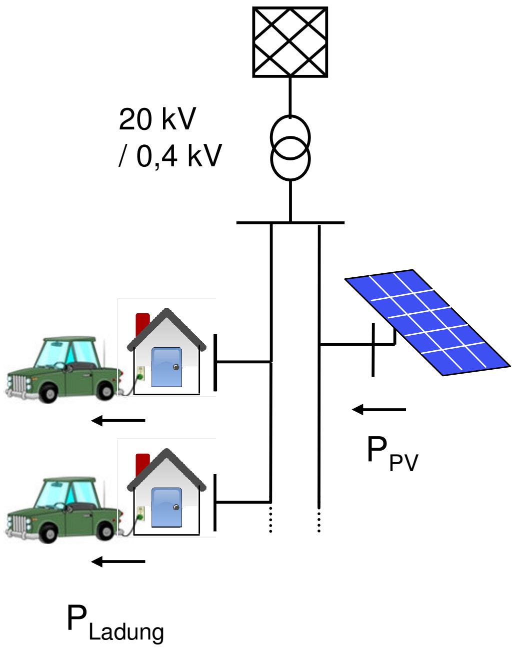
-> Energy = 20kWh x 4 mio cars = 80 GWh
(1 nuclear power plant running 3 days)

Uncontrolled Charging of EV



Uncontrolled Charging:
Charging starts when car is plugged-in

Uncontrolled Charging of EV



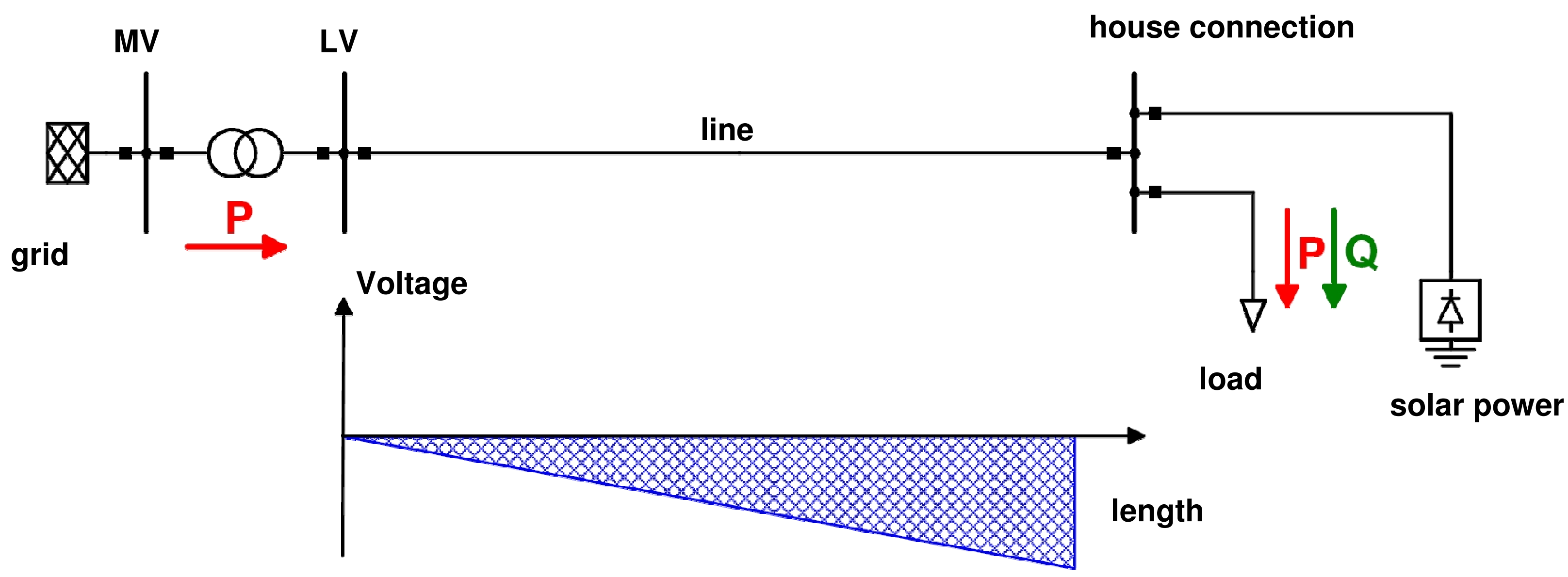
Simulation:

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

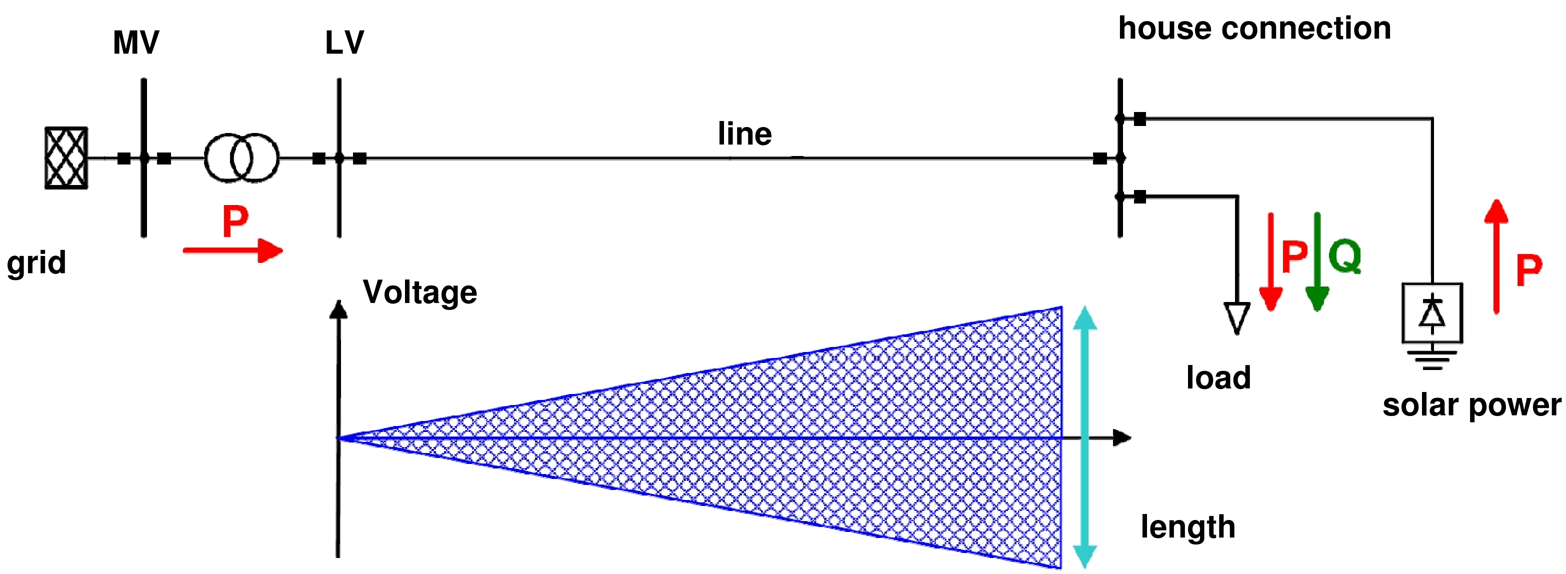
Low voltage grid: Load effects



With increasing load demand – decreasing voltage

- voltage no longer within specification
- transformer or line overload

Low voltage grid: Infeed effects

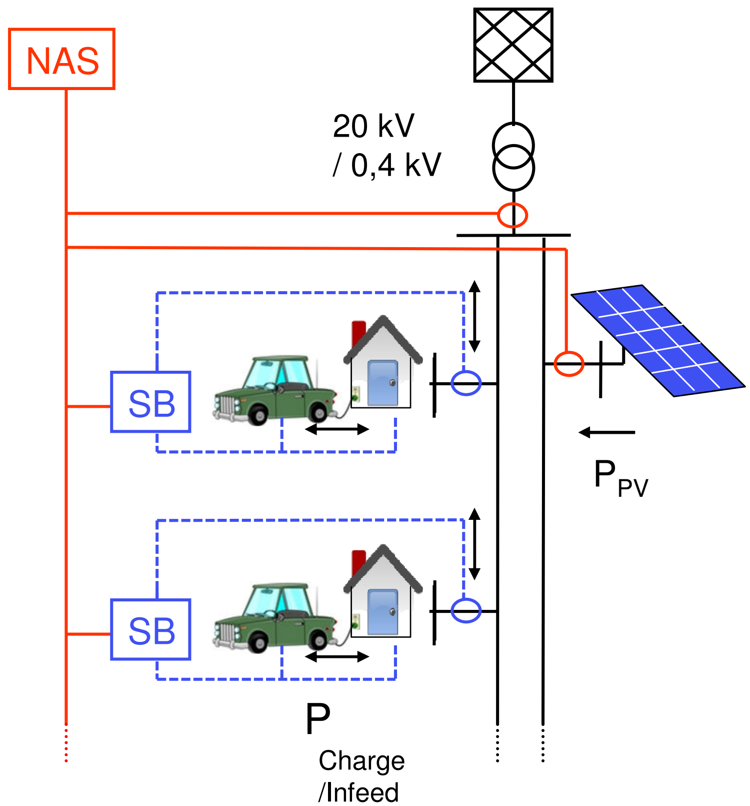


With increasing infeed – increasing voltage

- 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 <u>distributed vehicle batteries</u>

EV infeed in case of peak load demand

-> only parked and <u>plugged-in</u> EVs are able to support the electrical grid

Integration Strategies: Simulation

Strategy:

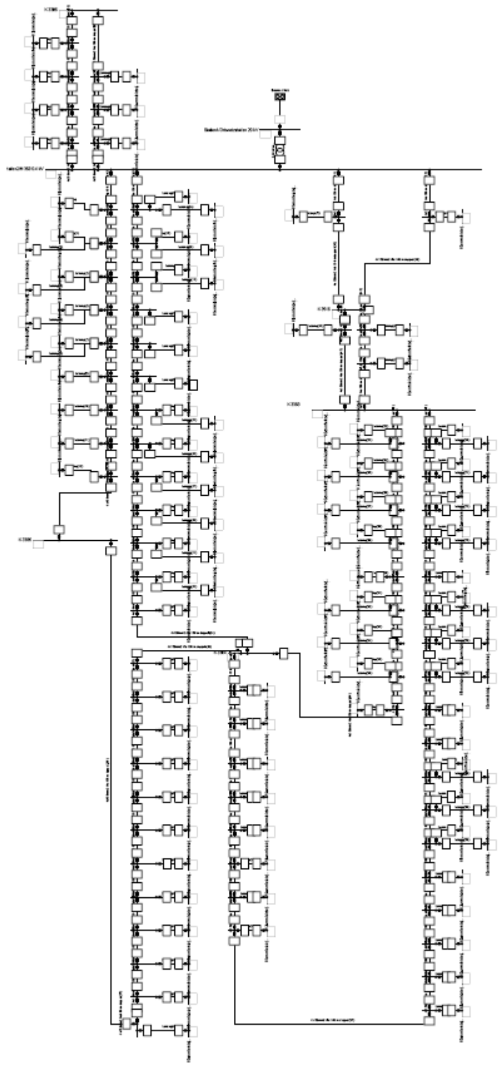
1) Controlled Drive Energy Charging:
Controlled EV charging during low power demand

-> 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



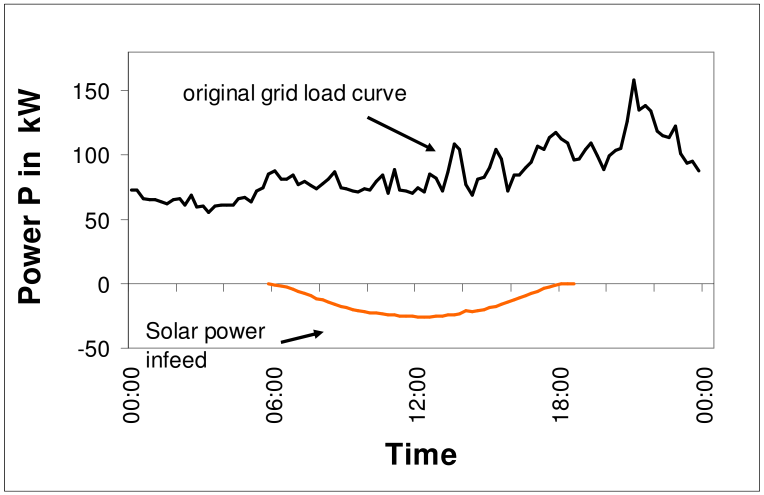
Grid Simulation considers:
-dynamical load demand of 100 households

- 20 Electric Vehicles:
  $P_{Charge/Infeed}$=10 kW
  $E_{Battery}$=20 kWh

-dynamical driving behavior:
  - typical drive ranges
  - typical departure/arrival times

Integration Strategies: Load Balancing Potential

1



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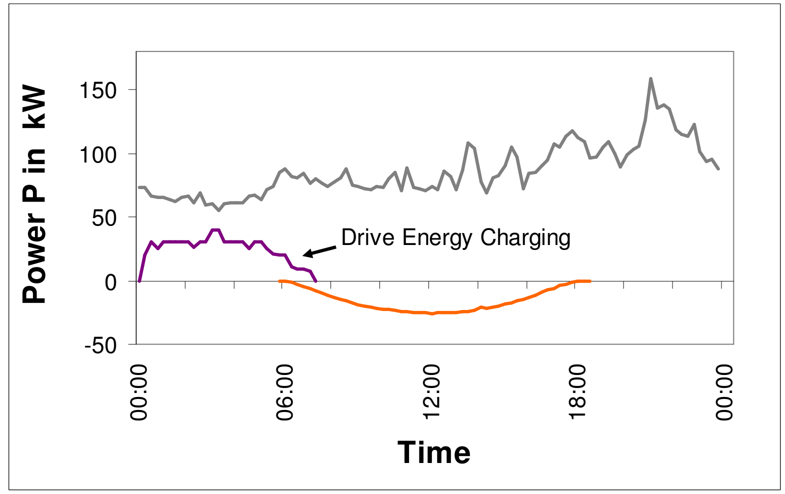

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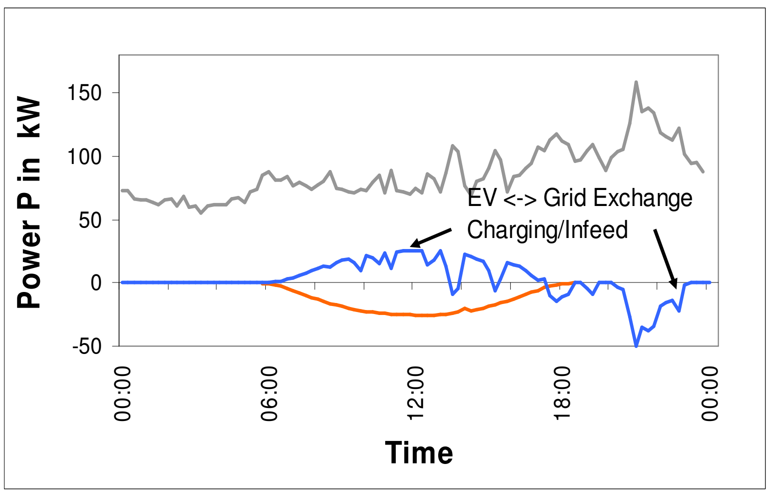

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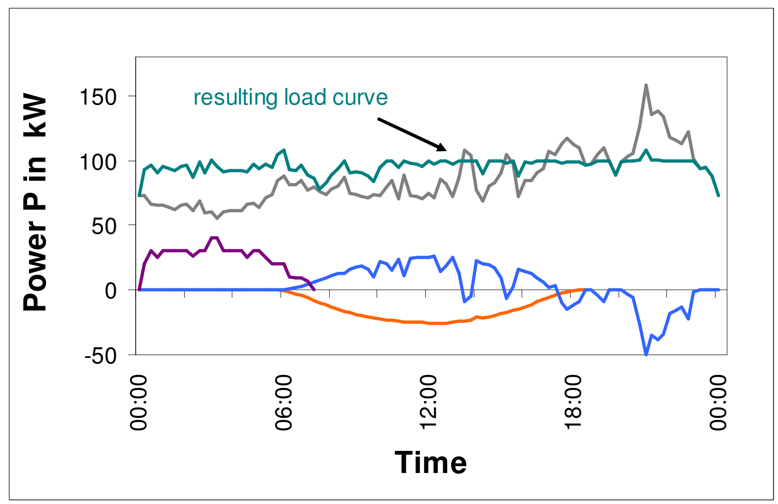

Conclusion:

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**