Grid Impact of Electric Vehicles with Secondary Control Reserve Capability

Thomas Degner,
Gunter Arnold, Ron Brandl, Julian Dollichon,
Alexander Scheidler

Division System Technology and Distribution Grids
Fraunhofer IWES
34119 Kassel, Germany

thomas.degner@iwes.fraunhofer.de

Contents:

- Introduction
- Impact on distribution grids in future scenarios with a large amount of electric vehicles
- Grid impact during a pilot test
- Tests of a group of electric vehicles with bi-directional charging station
- Conclusions

Fraunhofer
IWES

Introduction

INEES Project: Smart Grid Connection of Electric Vehicles Enabling Ancillary Services

Objective: Provision of secondary control reserve from a pool of electric vehicles

- Prototype like representation of entire system
  - Bi-directional, controllable, DC-charge management
  - Bi-directional charging station ("wall box"), 10kW
  - Pool manager as interface to energy markets
- Incentive scheme for users concerning active participation
- Pilot test
  - 20 Volkswagen "e-up!", operated 12 month in Berlin
  - Technology testing
  - User behavior and user acceptance
- Economics
  - Analysis of revenues from control reserve market
  - Analysis of costs (incl. battery ageing)
- Impact on distribution grids

- Partner:
  - Fraunhofer Institut für Windenergie und Energiesystemtechnik (IWES)
  - LichtBlick SE
  - SMA Solar Technology AG
  - Volkswagen AG (Project co-ordination)
- Duration:
  - June 2012 – May 2015
- Support:
  - Supported by the the Federal Ministry for the Environment, Nature Conservation, Building und Nuclear safety and the project agency VDI/VDE Innovation und Technik GmbH (contract number FKZ 16EM1016)

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Fraunhofer IWES

Introduction

INEES Project: Smart Grid Connection of Electric Vehicles Enabling Ancillary Services

Objective: Provision of secondary control reserve from a pool of electric vehicles

- Prototype like representation of entire system
  - Bi-directional, controllable, DC-charge management
  - Bi-directional charging station (“wall box”), 10kW
  - Pool manager as interface to energy markets
- Incentive scheme for users concerning active participation
- Pilot test
  - 20 Volkswagen “e-up!”, operated 12 month in Berlin
  - Technology testing
  - User behavior and user acceptance
- Economics
  - Analysis of revenues from control reserve market
  - Analysis of costs (incl. battery ageing)
- Impact on distribution grids

- Partner:
  - Fraunhofer Institut für Windenergie und Energiesystemtechnik (IWES)
  - LichtBlick SE
  - SMA Solar Technology AG
  - Volkswagen AG (Project co-ordination)
- Duration:
  - June 2012 – May 2015
- Support:
  - Supported by the the Federal Ministry for the Environment, Nature Conservation, Building und Nuclear safety and the project agency VDI/VDE Innovation und Technik GmbH (contract number FKZ 16EM1016)

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Fraunhofer IWES

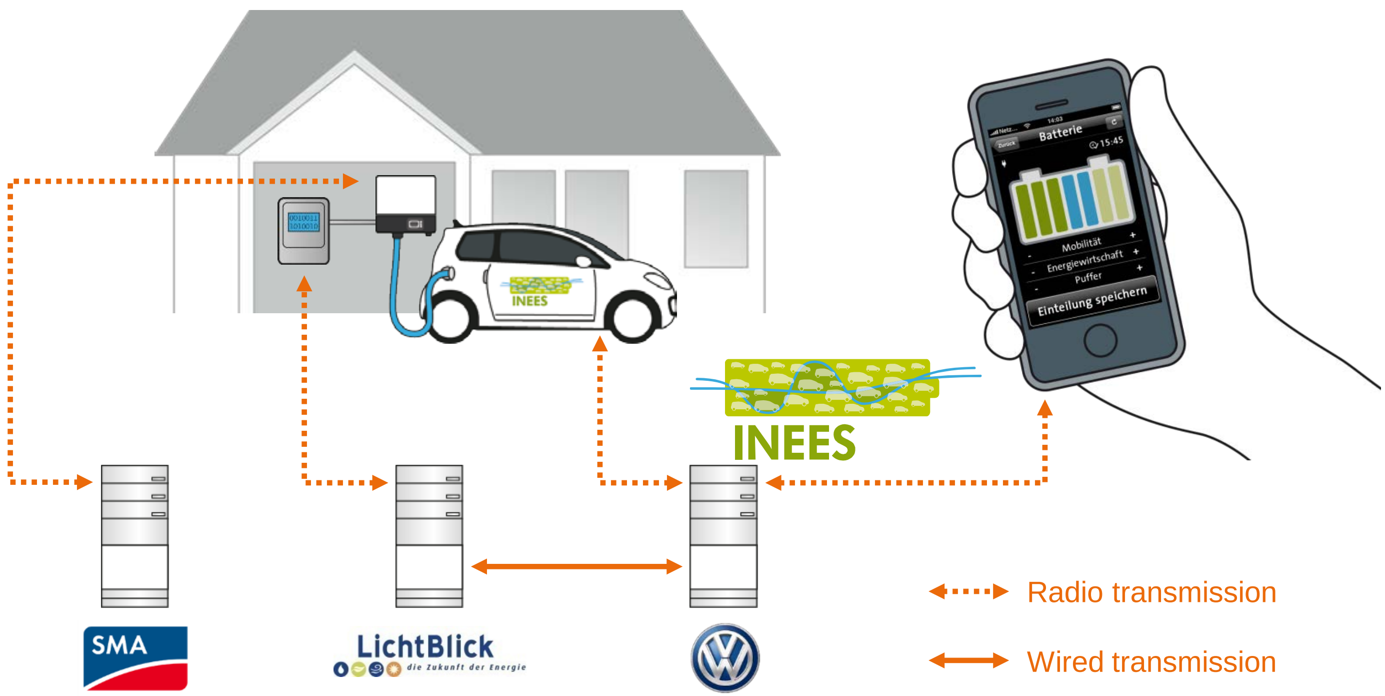
Introduction

INEES Project: Smart Grid Connection of Electric Vehicles Enabling Ancillary Services

Simplified representation of entire system

Source: Bäuml et.al. , BMU Vernetzungstreffen, 14th April 2013

- Subsystems:
  - Electric vehicle
  - Home installation (including charging station, meter, further measurement and communication devices)
  - User interface (e.g. iPhone)
  - Poolmanager (Lichtblick central)
  - Volkswagen Server Group
  - SMA server



Fraunhofer IWES

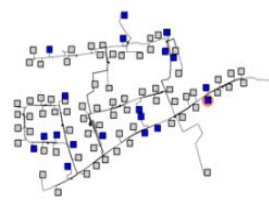
Analysis of Impact on Distribution Networks

Studies for low and medium voltage networks

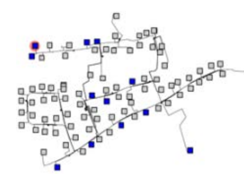
Objective: Identify critical penetration rates of electric vehicles (EV) in LV grids

- Studies of 310 LV networks
- For each single network 50 different scenarios were analyzed
- Each scenario was generated by placing EVs randomly at grid connection points until one the following limits was reached:
  - Voltage violation
  - Overload of cables
  - Over of transformer
- If one limit is reached the number of connected EVs is noted and a new scenario is started
- Consideration of 2 load cases:
  - High load and negative control energy
  - Low load, max. DG generation, positive control energy

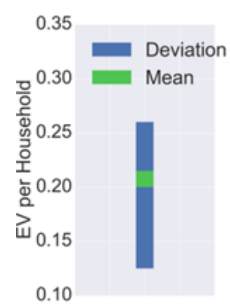
Example:



Scenario 1: Voltage violation with 25 EVs



Scenario 2: Voltage violation with 12 EVs



Analysis of 50 different randomly generated scenarios

Fraunhofer IWES

Analysis of Impact on Distribution Networks

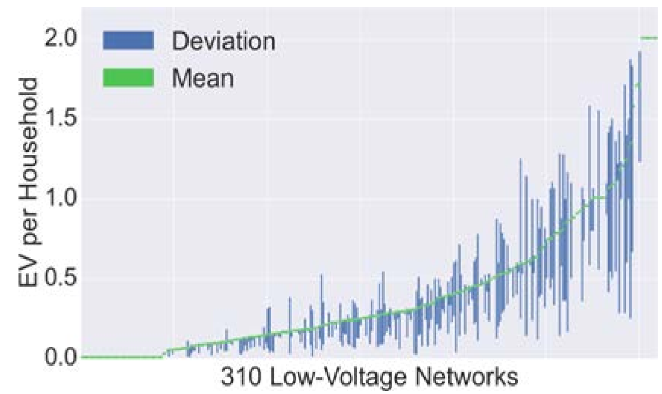
Studies for low and medium voltage networks

Objective: Identify critical penetration rates of electric vehicles (EV) in LV grids

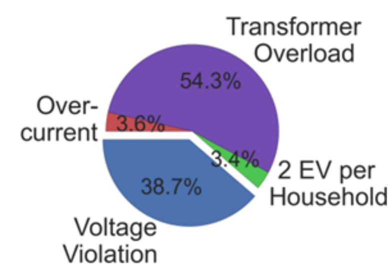
- Application to 310 LV networks

Results:

- Strong variations of hosting capacity for each single network
- 1/6 of the grids would not be able to host bi-directional feeding EVs (capacity already exhausted by installed DG)
- Mainly violations of voltage band and overloading of transformers
- Majority of studied networks are able to host bi-directional EVs at progressive EV penetration rates



Hosting capacity



type of expected constraint

Fraunhofer IWES

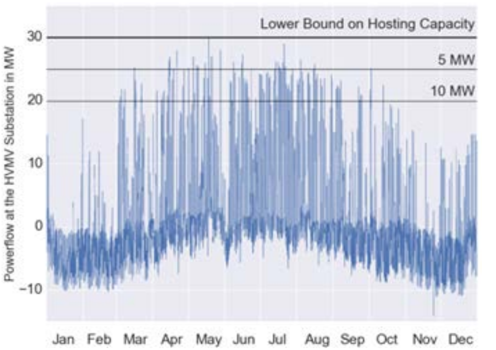
Analysis of Impact on Distribution Networks

Studies for low and medium voltage networks

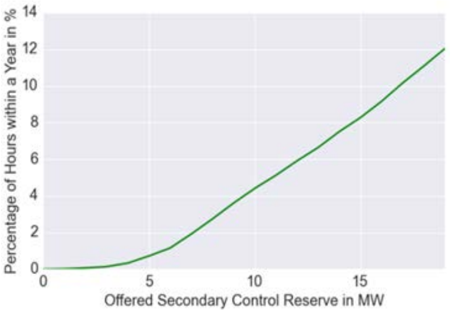
Objective: Avoidance of network overload over a HV/MV substation

Results:

- Measured power flow shows strong daily and yearly variation
- During periods of low DG generation free network capacity can be used for the provision of control reserve power.
- A pool manager could help to avoid network overloading



Measured power flow over a High Voltage / Medium Voltage substation



Percentage of hours the offered control reserve could not be provided.

Fraunhofer IWES

Analysis of Grid Impact During a Pilot Test

Measurement on the grid side of the charging station

Objective: Monitor any impact on the distribution grid during the pilot test

Approach

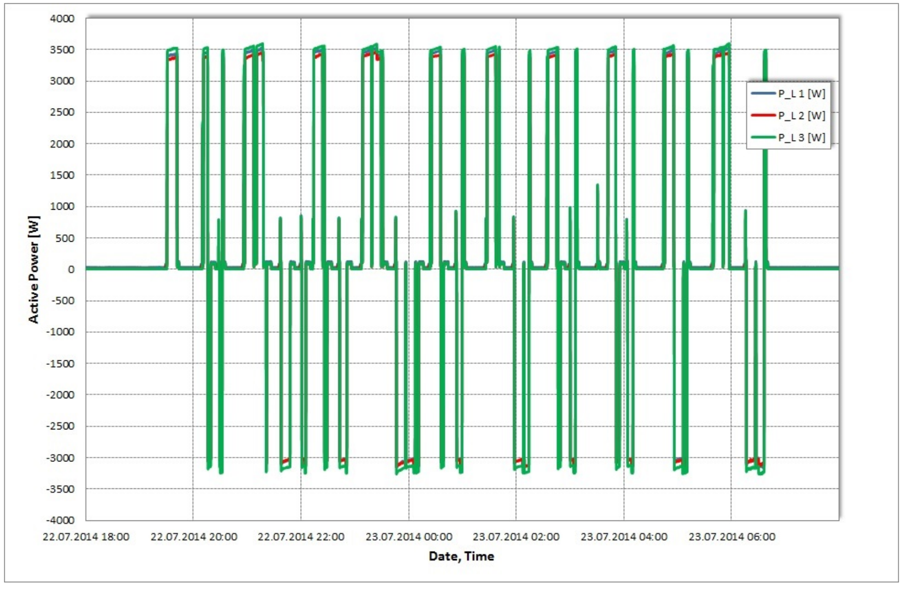
- Measurements at three charging stations
- Measurements of electrical power (active power, reactive power), voltages, currents
- Measurements of power quality parameters (voltages changes, flicker, harmonics)

Evaluation:

- Provision of control reserves (5s- values) temporal evaluation, dynamic precision)
- Interaction at the grid connection point between charging station and distribution grid

Results:

- Provision of active power is nearly perfect balanced to the three conducting lines
- Active power matches well the set value
- No violation of power quality parameters noted



Provision of control reserve according to a defined charge/discharge schedule from 22.7.2014 to 23.7.2014. Displayed are all 3 phases.

Charge / discharge schedule specified by pool manager

Fraunhofer IWES

Performance of a Group of EVs with Charging Stations

Investigations s in a close to reality laboratory environment

Objective: Functional and interaction testing

Approach

- Tests with four charging stations and four vehicles
- Charging station are connected to a physical low voltage grid branch
- Measurements of electrical power (active power, reactive power), voltages, currents and measurements of power quality parameters (voltages changes, flicker, harmonics)

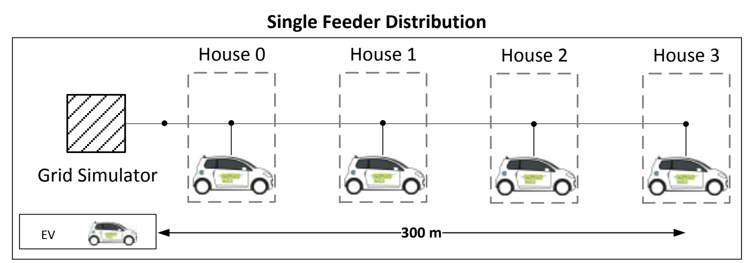
Evaluation:

- Provision of control reserves (5s- values) temporal evaluation, dynamic precision)
- Interaction at the grid connection point between charging station and distribution grid

Results:

- Provision of active power is nearly perfect balanced to the three conducting lines
- Active power matches well the set value
- No violation of power quality parameters noted

View of the experimental test setup in Fraunhofer IWES SysTec



Test setup for a single low voltage grid feeder

Fraunhofer IWES

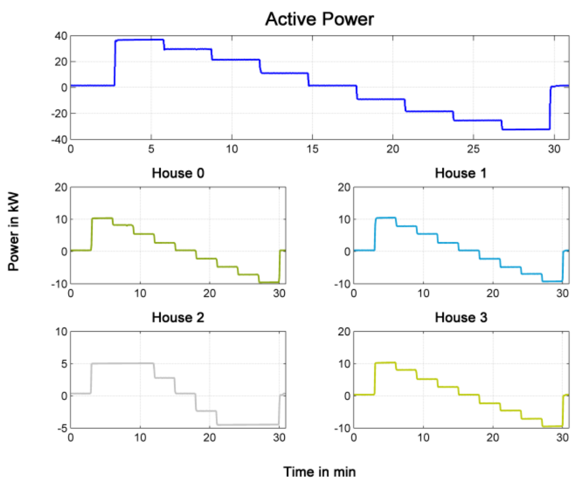
Performance of a Group of EVs with Charging Stations

Investigations s in a close to reality laboratory environment

Objective: Functional and interaction testing

Results (selection):

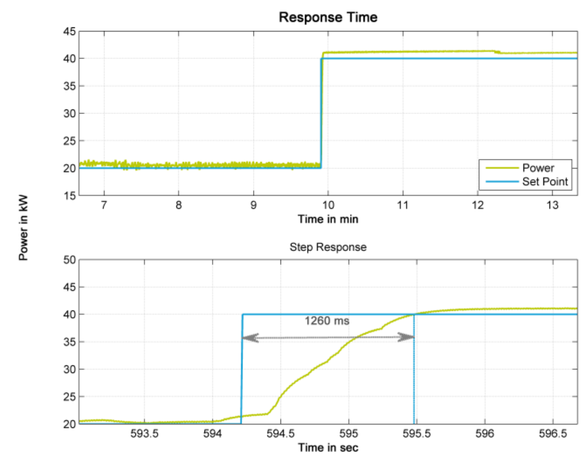
- Application of profiles for active power set point: group of systems follow the given active power set point



Individual (House 0, 1, 2, 3) power provision and total active power flow in the network (top figure, blue line)

Results (selection):

- Analysis of the dynamic settling time of a step request



Simultaneous control and dynamic of four systems, measured as total power flow over the network

Summary

- Under the assumptions of the study network congestions may to date occur only rarely
- Only networks which already have high loading may reach their capacity limits
- In the long term a high portion of electric cars may require extensive network extensions
- The operation of a small fleet of electric vehicles (pilot test) shows no strong impact on the distribution grid and does not lead to violation of limits given in power quality standards
- A system of four vehicles was tested in one grid feeder together with other distributed generation. Even while operating close to network limits the system performed well and as expected
- In conclusion, grid integration of electric vehicles with secondary control reserve could be demonstrated successfully

Outlook

- With increasing power of charging station impact on distribution grids increases
- Network planning must consider at least
  - charging demand
  - development of distribution generation
  - provision of ancillary services
  - smart grid technologies

  -> grid extension planning becomes a complex task
- Grid codes for charging stations must consider needs of TSO and DSO

Grid Impact of Electric Vehicles with Secondary Control Reserve Capability

Thank you for the attention!

Contact:
Thomas Degner

Division System Technology and Distribution Grids
Fraunhofer IWES
34119 Kassel, Germany

thomas.degner@iwes.fraunhofer.de

We acknowledge the support of our work by the Federal Ministry for the Environment, Nature Conservation, Building und Nuclear safety and the project agency VDI/VDE Innovation und Technik GmbH within the project INEES (contract number FKZ 16EM1016).

Only the authors are responsible for the content of the publication.

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Fraunhofer IWES