Impact of Different Charging Strategies for Electric Vehicles on their Grid Integration

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Is Controlled Charging of Electric Vehicles Blessing or Curse for their Grid Integration???
Merit Order Netzausbau (MONA) 2030
The Project MONA 2030 – Partners and Team

16 companies support MONA 2030…

… and enable therefore 15 man-years of research on the grid.
Approach – General set-up of the project

- Grid Topologies
- Load profiles
- Type Grid
- Merit Order
- Grid optimizing measures
- Scenarios

SIMULATION

Cost-benefit analysis
GridSim – The FfE Distribution Network Simulation Tool

Reference Variables
- Voltage
- Power
- Price

Combined load flow calculation and energy system model for distribution grids

Heat demand in MWh/a
Mobility demand in MWh/a
Electricity demand in MWh/a
GridSim – FfE Distribution Network Simulation Tool

Combined load flow calculation and energy system model for distribution grids

**Components:**
- Household Loads (3-phases)
- PV-Plants
- Electrical Storage System
- Power-to-Heat Plants
- Electric Vehicles
- Reactive Power Management
- Adjustable Transformer
- Line Voltage Regulator

**Reference Variables:**
- voltage
- power
- costs
Charging Control Strategies
Division of the EV Battery within three fundamental Sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>SoC &lt; SoC_{min}</td>
<td>Maximum charging power (independent of charging control strategy)</td>
</tr>
<tr>
<td>B</td>
<td>SoC_{min} &lt; SoC &lt; SoC_{Departure}</td>
<td>Charging Power depends on charging control strategy. If SoC_{Departure} will not be reached until departure: maximum charging power</td>
</tr>
<tr>
<td>C</td>
<td>SoC_{Departure} &lt; SoC</td>
<td>Charging Power depends on charging control strategy</td>
</tr>
</tbody>
</table>
Uncontrolled Charging

Start of Charge: As soon as the EV is connected

Charge Power: Maximum charging power regardless of the current SoC
Own Consumption Optimized Control

A: $\text{SoC} < \text{SoC}_{\text{min}}$
- Maximum charging power (independent of charging control strategy)

B: $\text{SoC}_{\text{min}} < \text{SoC} < \text{SoC}_{\text{Departure}}$
- Charging with PV surplus
- If $\text{SoC}_{\text{Departure}}$ will not be reached: Charging with maximum power before departure to reach $\text{SoC}_{\text{Departure}}$.

C: $\text{SoC}_{\text{Departure}} < \text{SoC}$
- Charging only with PV surplus
Price Oriented Control

<table>
<thead>
<tr>
<th>Condition</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: SoC &lt; SoC&lt;sub&gt;min&lt;/sub&gt;</td>
<td>Maximum charging power (independent of charging control strategy)</td>
</tr>
<tr>
<td>B: SoC&lt;sub&gt;min&lt;/sub&gt; &lt; SoC &lt; SoC&lt;sub&gt;Departure&lt;/sub&gt;</td>
<td>Charging during the cheapest times to reach SoC&lt;sub&gt;Departure&lt;/sub&gt; (perfect price forecast)</td>
</tr>
<tr>
<td>C: SoC&lt;sub&gt;Departure&lt;/sub&gt; &lt; SoC</td>
<td>Charging if Price &lt; 0,7 * Ø Price per Day (If the price is 30 % lower than the average of that day)</td>
</tr>
</tbody>
</table>
Voltage Guided Control

- **$U_{\text{household}} > U_{\text{critical, decrease}}$**: Charging Power: maximum charging power ($P_{\text{max}}$)

- **$U_{\text{min}} < U_{\text{household}} < U_{\text{critical, decrease}}$**: Charging Power: controlled in a linear way between $P_{\text{max}}$ and $P_{\text{min}}$ dependent of voltage level

- **$U_{\text{min}} > U_{\text{household}}$**: Charging Power: no charging
Impact of different Charging Control Strategies
Simulation Scenario

Type Grid 4

- 45 buildings / households
- 26 PV-Plants
- 10 Heat Pumps
- 23 Electric Vehicles
  - 7 BEV (47 kWh battery)
  - 16 PHEV (19 kWh battery)
- Charging Stations:
  - 12 x 11 kW (3-phases)
  - 11 x 3,3 kW (1-phase)
- $\text{SoC_{min}}$ 12 % (~ 30 km (BEV))
- $\text{SoC_{Departure}}$ 70 % (~180 km)
Maximum Charging Concurrency (Uncontrolled Charging)
Comparison Maximum Charging Concurrency

Uncontrolled

Own Consumption

Voltage Guided

Price Oriented
Power Duration Curve of the Transformer

Peak Load of price oriented control 2-3 x higher
Power Duration Curve of the Transformer

Peak Load of price oriented control 2-3 x higher
Voltage Reserve Duration Curve

The voltage reserve duration curve describes the minimum distance to the allowed voltage band boarders for each timestep in the whole grid area.
Voltage Reserve

Influence of the maximum charging power of the wallboxes on the Voltage Reserve

Charging Power: 3.3 / 11 kW

Charging Power: 3.3 / 22 kW
Voltage Reserve

Influence of the maximum charging power of the wallboxes on the Voltage Reserve

Charging Power: 3.3 / 22 kW
Conclusion

1. Controlled Charging can be blessing or curse!

2. The price oriented charging strategy leads to the highest charging concurrencies
   • Price oriented charging strategy: 94 %
   • Own consumption optimized control: 45 %
   • Uncontrolled Charging: 30 %

3. The price oriented charging strategy increases the peakload of the grid by more than 120 %

4. The best control strategy in respect to the system voltage is the own consumption optimized control
Discussion? Questions?

- Expectations
- Voltage Reserve
- Electric vehicles
- GridSim
- Simulation
- Grid Integration
- MONA 2030
- PV
- Storage
- Concurrency
- Charging Strategy

Questions?
Thank you for your attention!

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