Optimization Strategies for Electric Vehicle Charging Schedules

Master Thesis Defense
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Agenda

Motivation
Objectives & Justification
Charging Strategies
Test Environment
Case Studies & Results
Conclusions & Future Research
Motivation

- EVs are important to mitigate CO₂ emissions
- Uncontrolled EV charging poses a risk
- Realistic implementation for controlled charging is difficult due to multiple stakeholders
  - EV users
  - EV fleet aggregators
  - DSOs
- Traffic light concept as a common rule set for these stakeholders
  - Network status defined by three different colors: green, amber and red
  - DSOs are supervising networks and interact with market players if needed
Objectives of the Thesis

1. A new charging strategy for realistic implementation.
   - Separated DSO and the EV fleet aggregator
   - Unidirectional communication between the entities
   - Communication carried out by technical signal for power capacities

2. Compare against existing charging strategies

3. Investigate the effects of two EV fleet aggregators
Justification of the Topic

The implementations in reviewed publications are not realistic

- Combined entities or iterative solution finding for EV charging schedules
- Only global power capacity accounted as a constraint
- No comprehensive comparison
- No multiple EV fleet aggregators
Communication Based Strategy

Figure: Inputs and outputs for the CBS
# Charging Strategies

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Objective &amp; Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication Based Strategy (CBS)</td>
<td>Cost minimization, EV &amp; power capacities</td>
</tr>
<tr>
<td>Uncontrolled Charging Scenario (UCS)</td>
<td>Immediate EV charging</td>
</tr>
<tr>
<td>Aggregator Based Strategy (ABS)</td>
<td>Cost minimization, EV related</td>
</tr>
<tr>
<td>DSO Based Strategy (DBS)</td>
<td>Load flattening, EV &amp; network related</td>
</tr>
<tr>
<td>System Based Strategy (SBS)</td>
<td>Cost minimization, EV &amp; network related</td>
</tr>
</tbody>
</table>
Test Environment

Figure: Simulink model for the simulation system
Test Environment

- The electric network has a 630 kVA distribution transformer, accommodates 146 households and has 10 main feeders.
- The used data covers 48 hour time periods for
  - Wednesday-Thursday
  - Saturday-Sunday
- Two different EV penetration rates are applied
  - 75% EV penetration rate
  - 100% EV penetration rate
- Simulations are performed in On-line mode to attain the dynamic behavior of the models.
Comparison of Single Charging Strategies

Table: Simulation results on Wednesday with 75% EV penetration rate

<table>
<thead>
<tr>
<th>Scenario</th>
<th>UCS</th>
<th>ABS</th>
<th>DBS</th>
<th>SBS</th>
<th>CBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total charging cost [€]</td>
<td>85.7</td>
<td>23.2</td>
<td>59.6</td>
<td>28.2</td>
<td>24.9</td>
</tr>
<tr>
<td>Change of charging cost [%]</td>
<td>0</td>
<td>-73</td>
<td>-30.4</td>
<td>-67.1</td>
<td>-71.0</td>
</tr>
<tr>
<td>Net number of interruptions</td>
<td>0</td>
<td>-13</td>
<td>79</td>
<td>16</td>
<td>-7</td>
</tr>
<tr>
<td>Time flexibility [h]</td>
<td>12.1</td>
<td>2.6</td>
<td>1.5</td>
<td>3.4</td>
<td>3.2</td>
</tr>
<tr>
<td>Maximum current [A]</td>
<td>348</td>
<td>441</td>
<td>257</td>
<td>250</td>
<td>257</td>
</tr>
<tr>
<td>Violation magnitude [%]</td>
<td>22.4</td>
<td>55.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Violation duration [min]</td>
<td>8</td>
<td>32</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Change of network losses [%]</td>
<td>0.0</td>
<td>-19.6</td>
<td>-50.0</td>
<td>-35.3</td>
<td>-27.6</td>
</tr>
<tr>
<td>Cost of network losses [€]</td>
<td>8.0</td>
<td>1.6</td>
<td>3.1</td>
<td>1.6</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Comparison of Single Charging Strategies

Figure: Wednesday, electric network impacts
## Comparison of Single Charging Strategies

<table>
<thead>
<tr>
<th>Strategy:</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncontrolled Charging Scenario</td>
<td>Flexibility</td>
<td>Highest charging costs &amp; Large network impacts</td>
</tr>
<tr>
<td>Aggregator Based Strategy</td>
<td>Lowest charging costs</td>
<td>Large network impact</td>
</tr>
<tr>
<td>DSO Based Strategy</td>
<td>Smallest network impact</td>
<td>High charging costs</td>
</tr>
<tr>
<td>System Based Strategy</td>
<td>Low charging costs</td>
<td>Combined entities</td>
</tr>
<tr>
<td>Communication Based Strategy</td>
<td>Low charging costs</td>
<td>DSO calculation accuracy</td>
</tr>
<tr>
<td></td>
<td>Small network impact</td>
<td></td>
</tr>
</tbody>
</table>
Multiple EV Fleet Aggregators With Different Strategies

Figure: Multi aggregator flowchart
Multiple EV Fleet Aggregators
With Different Strategies

Figure: Wednesday, charging costs and change percentages

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Multiple EV Fleet Aggregators
With Different Strategies

Figure: Wednesday, net number of interruption and time flexibility
Multiple EV Fleet Aggregators
With Different Strategies

Figure: Wednesday, current violation magnitude and duration

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Multiple EV Fleet Aggregators With Different Strategies

Figure: Wednesday, costs and changes of network losses
Conclusions

- Robust and reliable
- Flexible for both entities
- Ideas successfully adopted
- Shortcomings avoided
- Potential for further development
Future Research

- Enhance the DSO calculation
- More comprehensive tests
- Implement V2G
- Power capacities to market based signals
Questions and Comments?

Thank you for your time.

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