Power system value of smart versus dumb charging of EVs

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Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

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Citation (APA):
Power system value of smart versus dumb charging of EVs

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Modelling EVs in the power system

- Model runs with Wilmar and Balmorel
  - Investment decisions and costs from Balmorel (www.balmorel.com)
  - Operational costs from Wilmar (www.wilmar.risoe.dk)
  - Both have EVs included
  - Example case: Finland 2035
  - Time-scale is hourly, geographic resolution is regions or countries
  - Both models include an EV module (Wilmar module made by VTT)

- Note!
  - Grid impacts not included (distribution grids may be heavily impacted)

- Kiviluoma, J., Meibom, P., Methodology for modelling plug-in electric vehicles in the power system and cost estimates for a system with either smart or dumb electric vehicles, Energy, epublished, DOI: 10.1016/j.energy.2010.12.053.
Generation investment model Balmorel

• Developed by Hans Ravn, RAM-løse edb
• Further development and usage: Risø DTU, EA Energianalyse, Cowi, Energinet.dk
• Balmorel is one of the few generation expansion models that handles wind power in hourly time scale
• The model optimises investments and operation of the energy system so that it can meet the loads from hour to hour over the whole year
  • Simplified to 26 weeks
  • Investment costs are annualised
  • Wind power is one of the investment options (at low price)
  • Includes CHP plants and heat boilers for district heating
  • No demand for reserves
  • Capacity adequacy requirement
Stochastic unit commitment and dispatch model
Wilmar

• Improve operational decisions in power systems (unit commitment and dispatch of units) by using not only:
  • The expected value of wind power and load forecasts
  • But also accuracy of forecast, i.e. the distribution of forecast errors

• Approach:
  • Hourly system-wide stochastic optimisation model with stochastic input parameters
  • Covering both day-ahead scheduling and rescheduling (up and down regulation) due to updated forecasts
  • Rolling planning with updated forecasts
  • Exogenously defined demand for positive spinning reserve
  • Endogenously defined demand for tertiary reserves (regulating power)
Dumb versus smart charging

- **Dumb charging:**
  - Vehicles start charging at maximum loading capacity as soon as plugged in and continues until batteries are full
  - No provision of reserves and no V2G
  - EVs have similar effects as wind: net load variability increases

- **Smart charging:**
  - V2G possible
  - Charging/discharging planned day-ahead
  - Rescheduling of charging/discharging plans possible intra-day
  - EVs can provide spinning and tertiary reserves by reserving charging/discharging capacity

- Cases are extreme: all EVs are smart or all EVs are dumb charging
Modeling of vehicle behaviour

- Data from the Finnish National Transport Survey 2004-2005
- The share of arriving and departing vehicles for each hour
- Accounts for the variation in average distance travelled
- Separately for weekdays, Friday, Saturday, Sunday, official holidays, and days between a weekend and a holiday
- Weekly index to accommodate inter-annual variation
- Departure and arrival are linked
Modeling of EVs

- EVs modeled as electricity storages not always connected to the power grid and while gone, spend some of their stored electricity
- Each vehicle type has its own general electricity storage pool in each model region
- Leaving vehicle takes required amount of electricity from the storage pool
- It also takes away the amount of storage capacity its battery has and gives it back upon arrival
Study setup

EVs
- ½ million full electric vehicles (FEVs), ½ million PHEVs
- 200 km driving range for FEVs
- 100 km driving range of PHEVs
- Plug-in pattern:
  - 98% at home
  - 20% at work
- Driving pattern:
  - On average 3 trips per day
  - Combined distance of 52 km
  - Charging opportunity every 39 km
- Usable storage size
  - Fluctuates
  - Around one hour of peak demand
  - EVs leaves grid with full batteries

Storage capacity and usage (model results)

Storage capacity & charging [MW]

Storage [MWh] & charging [MW]

Charging/discharging

Thurs  Friday  Satur  Sunda

Risø DTU, Technical University of Denmark
## Capacity of New Power Plants in the Different Balmorel Scenarios

<table>
<thead>
<tr>
<th>Power Plant Type</th>
<th>No EVs</th>
<th>MW of Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dumb</td>
</tr>
<tr>
<td>NatGas comb. cycle cond.</td>
<td>363</td>
<td>520</td>
</tr>
<tr>
<td>NatGas open cycle cond.</td>
<td>2861</td>
<td>3580</td>
</tr>
<tr>
<td>Nuclear</td>
<td>5312</td>
<td>5688</td>
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<tr>
<td>Wind</td>
<td>4705</td>
<td>5130</td>
</tr>
<tr>
<td>Forest residue CHP</td>
<td>1203</td>
<td>1206</td>
</tr>
<tr>
<td>Wood waste CHP</td>
<td>76</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smart</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
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<td>1192</td>
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<td>75</td>
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</table>
Calculating benefits of smart charging by comparing model runs

<table>
<thead>
<tr>
<th></th>
<th>Balmorel run</th>
<th>Wilmar run</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spinning reserve</strong></td>
<td>Smart</td>
<td>Smart</td>
</tr>
<tr>
<td></td>
<td>Smart</td>
<td>Smart no spin</td>
</tr>
<tr>
<td><strong>Intra-day flexibility</strong></td>
<td>Smart</td>
<td>Smart no spin</td>
</tr>
<tr>
<td></td>
<td>No 500</td>
<td>Smart, no spin, no intra-day flexibility</td>
</tr>
<tr>
<td><strong>Day-ahead planning</strong></td>
<td>No 500</td>
<td>Smart, no spin, no intra-day flexibility</td>
</tr>
<tr>
<td></td>
<td>Dumb</td>
<td>Dumb</td>
</tr>
</tbody>
</table>
BENEFITS OF SMART CHARGING

Total 227 €/vehicle/year

Day-ahead planning 36%
Spinning reserves 17%
Intraday flexibility 47%
SYSTEM VS. MARKET BENEFITS

- System benefit of smart EVs
- Market benefit of smart EVs
- Market price of smart EVs
- Market price of dumb EVs

€/vehicle/a
### VEHICLE-TO-GRID

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cost over Base (€/vehicle/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No V2G allowed</td>
<td>53</td>
</tr>
<tr>
<td>V2G half of the vehicles</td>
<td>6,7</td>
</tr>
</tbody>
</table>
Conclusions

- Smart charging allows for higher amount of wind power
- Timing of charging constitutes main part of benefit with V2G less important
- Benefit for vehicle users of smart charging only 25% of socio-economic benefit
- Benefit of V2G mostly related to provision of spinning reserves
- 87% of V2G benefit can be provided by equipping half of the vehicles with V2G