EDISON Demo A: Fleet operation for mutual benefit

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The overall purpose of the EDISON Workpackage 3 is the development of a server-side management system to control the charging of cars in accordance with the availability of wind energy while enabling optimal use of the electricity grid.
1. Motivation of Grid-aware Smart Charging
   a. Aggregated-level benefits
   b. Individual driver perspective

2. Video of Bornholm Grid and EV Simulation

3. Panel of Fleet Operator

4. Virtual EVs and Archive Visualization

5. EV and Fleet Management - Bornholm
With today's flat prices, EVs will charge immediately after trips. The typical day curve with peaks of power required on "arrival at work" and "back home" late afternoon / early evening will get even higher as mobility migrates off fossil and onto electricity grid as main energy backbone.

**Direct Charging**
- Marginal power is high in carbon content
- Large impact on grid
- Large variations in base generation, need of balancing power
2. Dynamic electricity prices enable savings

Offering e.g. the dynamic day-ahead prices to consumers and EVs enables savings. But broadcasting dynamic prices is not sufficient and leads to "lemming" effects.

With the pre-announced cheapest price early night, everybody might want to quickly start charging right then. Given large numbers of smart consumers and EVs, this can be very dangerous with worse peaks than ever before with flat prices.

Minimize Cost of Charging
- Price is correlated with wind power
- Lemming-effect, all vehicles charge at low priced slots
- Large impact on grid
- Large variations in base generation, need of balancing power
3. Use excess wind power to increase green content

Offering the dynamic day-ahead prices to consumers and EVs enables savings. The objective to fully use the available wind removes the "lemming" effect.

While the shift of consumption off main load peaks enables savings, this also increases the renewable content. Extra wind lowers price. Of course the charging has to be automatic, at 2AM while we sleep.

Charge when wind is available in excess of base consumption
- If necessary charge also if wind power is lower than base consumption
- Still large variations in base generation, need of balancing power
Essentially, EVs can easily absorb load and wind fluctuations for grid operators, already by just varying the charging intensity, at the level of the aggregated fleet.

This strategy should be seen as a didactic step to explain the potential but also the potential problem with this.

**Absorb Fluctuations**
- Use EV fleet to level out fluctuations in base generation
- Stable operation of conventional generating units, which leads to the possibility to increase share of wind power
- High cost of charging
- Low green content of energy
Joint analytics and a two-way data exchange on driving predictions, charging requirements, grid state and constraints, and wind and price expectations leads to the optimal symbiotic solution.

The mixed objective is to reduce costs, use green wind energy, and reduce fluctuations.

**Mixed Objective Charging**
- Minimize cost of charging
- Use of excess wind power
- Absorbing wind fluctuations
- Dampen requirements on base generation dynamics

While the ultimate algorithms and distributed strategies are subject to continued work, the establishment of a smart-charging enabled infrastructure is a necessary first step. This ECO mode is for the masses, the individual is always VIP.
6. EV driver can always ask for VIP (direct) charging

The driver should always remain in the driver seat.

Requesting direct charging provides the energy directly after connection to the charging spot.

In general, there is enough time left, to incrementally recharge after trips

*if* we can assume that not driving means being connected.
7. ECO (smart) charging gives EV driver same range

For a particular EV driver with his/her typical driving patterns, some charging could happen later without violating driver's needs.

With predictable driving patterns for commuters and family cars, there is typically a substantial battery charge left at the end of trip.

Smartly shaping the charging according to wind and price predictions provides the same energy in ECO mode without any usability penalties.
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Summary of Fleet operation for mutual benefit

1. Grid-aware smart-charging leads to enormous benefits for EV owners, Grid operators, and Society as a whole
2. Also the individual driver benefits in ECO mode, while direct charging in VIP mode is available as usual
3. The establishment of a smart-charging enabled infrastructure is a necessary precondition
4. Our ICT platform is ready for a Bornholm demonstration in 2011!
Backup and Screenshots
Green power for E-Mobility demonstrator
Simulation video of Grid-aware optimized EV charging

Source: Olle Sundstroem and Carl Binding, IBM
The EDISON Fleet Operator EVPP Panel

The EVPP Aggregator Panel visualizes the fleet operators interaction with Grid, Market and Fleet.

- The EVPP’s operation is based on market prices.
- The EVPP optimizes the charging of vehicles without limiting driving behavior.
- The EVPP adjusts its optimization to local grid constraints.
EDISON Operator Panel

home  fleet  market  control panel

Static Car Information

<table>
<thead>
<tr>
<th>ID</th>
<th>License P.</th>
<th>Brand</th>
<th>Model</th>
<th>Batt. Size</th>
<th>Ch. Power</th>
<th>Dch. Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>AG12345</td>
<td>Citroen</td>
<td>C1</td>
<td>53,0kWh</td>
<td>2.50kW</td>
<td>0.00kW</td>
</tr>
</tbody>
</table>

EV status

State of Charge
59%

Current Status
Charging

Last seen
17.8.2010 20:27:49

EV Availability – Expected and Real

Market Prices

Live EV State

Charging Schedule (load/kW)

Charging Schedules
IEC 61850 based EDISON virtual EV & CS simulator
EDISON - Electric vehicles in a distributed and integrated market using sustainable energy and open networks

CirroSphere – Fleet operator and EV driving archive interface

Source: cirrosphere.zurich.ibm.com/edison
Bornholm infrastructure database

Real-world data, including addresses and locations of interest for Bornholm.
Driving pattern generation

- Random homes, workplaces and other locations of interest are selected at random.

- Interviews with real-life drivers are used to ensure things like realistic departure times and commuting distances.

- Using publically available routing services, realistic routes are created for the driving patterns.
EV Driving Patterns and Fleet Management - Bornholm
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VPP forecasting & power balancing

Environmental data
(weather, calendar, events…)

Generation schedule(s)

Estimate charging power schedule

Historical data:
Trip data
Charging power consumption

P_{\text{max}}(t) \leq P_{\text{req}}(t)

P_{\text{req}}(t)

P_{\text{max}}(t) \leq P_{\text{req}}(t)

Environmental data
(weather, calendar, events…)

Outlet constraints?

P_{\text{max}}(t) \leq P_{\text{req}}(t)

Generation schedule(s)

Accu constraints?

P_{\text{max}}(t) \leq P_{\text{req}}(t)

P_{\text{req}}(t)

Feeder constraints?

P''_{\text{max}}(t) \leq P_{\text{req}}(t)

Sub-station constraints?

P'''_{\text{max}}(t) \leq P_{\text{req}}(t)

Balancing constraints?

Balance EV charging power down/up:

P_{\text{delivered}}(t) \leq P'''_{\text{max}}(t) \leq P_{\text{req}}(t)
VPP data flows to enable smart charging

- Trip info
- EV charging statistics
- Grid status
- EV charging schedule
- Production schedule(s)
- Weather forecast
- Production level(s)
- EV charging updates/changes
- Regulating up/down

[Images and logos for IBM, EURISCO, SIEMENS, DONG energy, ÖSTKRAFT, and DTU]