Analysis of electric vehicle interconnection with commercial building microgrids

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http://eetd.lbl.gov/EA/EMP/emp-pubs.html

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April 06, 2011

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Outline

- global concept of microgrid and electric vehicle (EV) modeling
- Lawrence Berkeley National Laboratory’s Distributed Energy Resources Customer Adoption Model (DER-CAM)

presentation summary

*How does the number of EVs connected to the building change with different optimization goals (cost versus CO₂)?*

ongoing EV modeling for California: the California commercial end-use survey (CEUS) database, **objective:** 138 different typical building - EV connections and benefits

detailed analysis for healthcare facility: optimal EV connection at a healthcare facility in southern California

conclusions
Global concept

single building at the building site

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The Distributed Energy Resources Customer Adoption Model (DER-CAM)
DER-CAM

- is a deterministic Mixed Integer Linear Program (MILP), written in the General Algebraic Modeling System (GAMS®)
- minimizes annual energy costs, CO$_2$ emissions, or multiple objectives of providing services to a building microgrid
- produces technology neutral pure optimal results, delivers investment decision and operational schedule
- has been designed for more than 9 years by Berkeley Lab and collaborations in the US, Germany, Spain, Portugal, Belgium, Japan, and Australia
- first commercialization and real-time optimization steps, e.g. Storage & PV Viability Optimization Web-Service (SVOW), http://der.lbl.gov/microgrids-lbnl/current-project-storage-viability-website
Major Optimization Results for a Healthcare Facility in San Diego Gas and Electric Service Territory
Different optimization goals

Multi-objective frontier (minimize the combination of costs and CO$_2$ emissions for building)

$$\min \left( (1 - \omega) \cdot \frac{Cost}{ReferenceCost} + \omega \cdot \frac{CO_2emissions}{ReferenceCO_2emissions} \right)$$
connected EVs reach maximum around “min cost” solution ($w=0$)
with increasing $w$: stationary batteries become more attractive to building than EVs → second life of EV batteries?
The California Commercial End-Use Survey (CEUS) Database
objective / final EV project goal: EV modeling at 138 buildings\(^x\) in nine climate zones

\(^x\) hospitals, colleges, schools, restaurants, warehouses, retail stores, groceries, offices, and hotels
2020 Equipment Options, Tariffs, and Building Analyzed
Equipment

- EVs belong to employees/commuters
- EVs can transfer energy to the building and vice versa
- the building energy management system (EMS) can manage (charge/discharge) the EV batteries during connection hours
- EV owner receives exact compensation for battery degradation and energy delivered to the building

<table>
<thead>
<tr>
<th>Equipment Parameter</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV-building connection period</td>
<td>8am – 5pm</td>
</tr>
<tr>
<td>EV-home connection period</td>
<td>7pm – 7am</td>
</tr>
<tr>
<td>EV battery state-of-charge (SOC) when arriving at the facility</td>
<td>73%</td>
</tr>
<tr>
<td>EV battery SOC when leaving the healthcare facility</td>
<td>≥32%</td>
</tr>
<tr>
<td>EV battery charging efficiency</td>
<td>95.4%</td>
</tr>
<tr>
<td>EV battery discharging efficiency</td>
<td>95.4%</td>
</tr>
<tr>
<td>EV battery capacity</td>
<td>16 kWh</td>
</tr>
<tr>
<td>Maximum EV battery charging rate</td>
<td>0.45 [1/h]</td>
</tr>
</tbody>
</table>
also combined heat and power (CHP), PV, solar thermal, stationary battery, etc. is considered in the analysis

technology costs in 2020 are based on “Assumptions to the Annual U.S. Energy Outlook”, e.g.
- fuel cell with heat exchanger: $2220 - $2770/kW, lifetime: 10 years
- internal combustion engine with heat exchanger: $2180 - $3580/kW, lifetime: 20 years
- PV: $3237/kW, lifetime: 20 years
- stationary battery: $193/kWh
- etc.

Building / tariffs

- electricity and gas loads for a San Diego healthcare facility are based on CEUS
  - peak electric demand: 399 kW
  - annual electricity demand: 2.33 GWh
  - annual natural gas consumption: 2.13 GWh (72700 therm)

- TOU rates and demand charges:
  - on-peak electricity up to 0.13 $/kWh
  - off-peak rates around 0.09 $/kWh
  - demand charges up to 12.8 $/kW-month

- electric rate at residences (homes) for EV charging: $0.138/kWh
Optimization Results for Summer Days

Optimal Investments in DER Technologies and Operation, Optimal EV Discharging / Charging subject to different building strategies
Diurnal electric pattern for min cost

EVs are used to reduce utility costs during expensive peak hours

draft results

EVs connect to building

EVs disconnect

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Diurnal electric pattern for point S1

- EVs are used to reduce utility costs during expensive peak hours
- PV is NOT used to charge EVs

**draft results**
Diurnal electric pattern for point S3

- big stationary battery
- stationary batteries charged by PV
- no EV batteries

Draft results
Diurnal electric pattern for point S4

- stationary battery > EV
- some EVs charged in the afternoon
Conclusions
Storage conclusions

- EV Charging / discharging pattern mainly depends on the objective of the building (cost versus CO$_2$)
- performed optimization runs show that stationary batteries are more attractive than mobile storage when putting more focus on CO$_2$ emissions. Why? Stationary storage is available 24 hours a day for energy management more effective
- stationary storage will be charged by PV, mobile only marginally
- results will depend on the considered region and tariff
  - final work will show the results for 138 different buildings in nine different climate zones and three major utility service territories
Thank you!

Questions and comments are very welcome.
DER-CAM literature


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High-level schematic

Example Constraints
- energy balance – supply & demand
- financial – payback
- technical – roof area for PV

Customer Load
(hourly by enduse)

Optimal Technology Choices

Other Outputs
i.e., costs, energy use, emissions

DER-CAM

Market Info
(tariffs, fuel prices)

Hourly Optimal Operating Schedule

Energy Sales

DER Technology Info
(generation, solar collection, & CHP)

DR Input Parameter
Representative MILP

Simplified* DER-CAM model

Objective function, e.g. min. annual energy bill for a test year:
+ energy purchase costs
+ amortized DER technology capital costs
+ annual O&M costs
+ CO₂ costs
- energy sales

Operational constraints
- generators, chillers, etc. must operate within performance limits
- heat recovered is limited by generated waste heat
- solar radiation / footprint constraint

Financial constraints
- max. allowed payback period, e.g. 12 years

Regulatory constraints
- minimum efficiency requirement
- emission limits
- CO₂ tax
- CA min. eff. requirement for subsidy and (in future) feed-in tariff
- ZNEB

Storage and DR constraints
- electricity stored is limited by battery size
- heat storage is limited by reservoir size
- max. efficiency potential for heating and electricity

Energy balance
+ energy purchase
+ energy generated onsite
= onsite demand + energy sales

*does not show all constraints