What Plug-in Hybrid-Electric Vehicles Can Do for the Grid?

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November 2, 2007
What is the Opportunity for PHEVs and EVs?

Opportunity for Grid-to-Vehicle (G2V)?

Opportunity for Vehicle-to-Grid (V2G)?
Grid Impact Study* of High Penetration Scenarios for PHEVs

* funded by Office of Electricity Delivery and Energy Assurance

Can the U.S. electric grid become a strategic national asset for addressing our dependence on foreign oil?

- How much energy could the idle capacity of the grid deliver for the U.S. light duty vehicle fleet (cars, pickups, SUVs, vans)?
  - assume grid looks much like today’s (worst case; likely to be cleaner)
  - assume vehicle mix is unchanged (worst case; likely to be lighter)
  - i.e., don’t allow outcome to be driven by assumptions about the future power plant mix or vehicle fleet

- What would be some of the impacts be on:
  - gasoline/crude oil displacement
  - emissions
  - utility revenue requirements
Fundamental Approach 1: Determine Available Marginal Generation

Assumptions:
No additional generation from existing:
- Nuclear
- Hydro
- Renewables
- Combustion Turbines (peaking plants)
Fundamental Approach 2: “Fill the Valley” in the Load Shape

Assumption:
Additional valley-filling generation constrained to lesser of:
- Available marginal generation @ 85% capacity factor
- Peak load
Coal, Nat. Gas Power Plants Fill the Valley

Summary
- Determine size of valley in MWh
  - Floor: average day in the peak season
  - Ceiling: lesser of available marginal generation @ 85% or peak load
- No marginal added generation in valley from:
  - Hydro
  - All other renewables
  - Nuclear
  - Peaking plants
Over 70% of the existing U.S. light-duty vehicle fleet (if PHEVs) could be fueled with available off-peak electric capacity.

**Assumptions**
- PHEV specific energy requirements (EPRI 2004):
  - Compact: 0.26 kWh/mi
  - Mid-size: 0.30 kWh/mi
  - Mid-size SUV/Vans: 0.38 kWh/mi
  - Full-size SUV: 0.46 kWh/mi
- 87% charger efficiency
- 85% battery efficiency
- 8% T&D loss
Analysis by NERC Region*

Summary

- **Midwest**: support almost the entire LDV fleet
- **East**: somewhat smaller potential
- **West**: supports fewer vehicles

% figures denote the percentage of LDV fleet supported by idle electric capacity
Increased Sales of Electricity from PHEVs Produce Downward Pressure on Electricity Rates*

* analysis of Cincinnati Gas & Electric and San Diego Gas & Electric

Cincinnati Gas & Electric Costs/MWh with PHEV Valley Filling

Increased sales

+ 

Same infrastructure, same capital investment

= 

Lower electricity rates
Opportunity of National Significance

The idle capacity of the U.S. grid could supply 73% of the energy needs of today’s cars, SUVs, pickup trucks, and vans… without adding generation or transmission.

Potential to displace 52% of net oil imports (6.7 MMbpd)

- More sales + same infrastructure = downward pressure on rates
- Reduces CO₂ emissions by 27%
- Emissions move from tailpipes to smokestacks (and base load plants) … cheaper to clean up
- Introduces vast electricity storage potential for the grid

Source: EIA, Annual Energy Review 2005
Current Generation and “Valley-Filling” CNV, Summer

![Graph showing energy generation for CNV, Summer, with bars for different energy sources and lines indicating Summer peak.]
Current Generation and “Valley-Filling”
ECAR, Summer
Perfect Valley Filling
ECAR Summer Load Profile

Charge each PHEV: 1.4 kW charge \((120V, 12A)\) for 7 hours = 10 kWh
Smart Grid Can Deliver Electricity to Millions of PHEVs

ELECTRIFYING THE TRANSPORTATION SECTOR WITH Plug-in Hybrid Electric Vehicles

The Smart Grid Can Deliver

- Market
- Smart grid
- Demand response

Benefits:
- Enhanced energy security
- Reduced greenhouse gases
- Improved urban air quality
- Increased grid asset utilization

“Valley Filling” (Energy for PHEVs)

“It’s in our vital interest to diversify America’s energy supply—the way forward is through technology... We need to press on with battery research for plug-in and hybrid vehicles...” — George Bush

“Unused off-peak U.S. grid capacity could supply 70% of the energy for today’s light vehicles and reduce foreign oil imports by 50%, without adding generation or transmission.” — Pacific Northwest National Laboratory

“Nationwide adoption of plug-in hybrids will increase the use of domestically produced electricity and can ultimately reduce greenhouse gas emissions by up to 800 million tons per year.” — EPRI

“Rarely in history has an emerging technology afforded such an attractive opportunity... as both a new load and resource, to enhance overall performance of the electric power infrastructure.” — National Renewable Energy Laboratory

“Working with automakers and local utilities, we need to understand how large numbers of PHEVs will be used, and their effect on the grid.” — University of Michigan
Why Is There So Much Talk About V2G?

Customer’s perspective:

- PHEV economics are unclear given other competing alternatives. Revenue (cash-back) for grid-services may provide more economic incentives for rapid market growth
- V2H (vehicle-to-home) provides backup power

Utility’s perspective:

- Energy storage is desirable for grid operation
  - Regulation and spin reserve purpose
  - Economic dispatch
- Meeting growing ancillary services requirements because of RPS
  - CAISO: Current regulation: 350 MW, with RPS: 500-700 MW
  - BPA: Current regulation: 150 MW, with RPS: 500+ MW
- Innovative ownership model of PHEV batteries
  - Leasing to Owner
  - Re-purposing batteries after life for transportation
- Carbon credits
Migration from Smart Charging to V2G

Smart charging is:

- Grid-aware
- Cash-back from regulation services ($2 - $5K) to offset the higher first cost of
- Batteries
- Communications
- Metering
Regulation Signals for California

1 Hour 1 Hour 1 Hour 1 Hour 1 Hour

350 MW

5-20 generators = 35,000 vehicles (10 kW)

Deeper Cycles over 1 hour

Shallow Cycles over 2-3 min

ACE

Regulation

Time [Sec]
Multi-Use of Batteries Impacts Life

**V2G: Shallow cycles, 2-min duration**
900K - 2,000K cycles in 5-10 yrs.

**V2G: Deeper cycles, 1-hour duration**
30K - 60K cycles in 5-10 yrs.

**Drive Cycle: Deep cycle: 1-day duration**
2K - 4K cycles in 5-10 yrs.

Assumed: resource availability (acc. AC Propulsion): 5 days/week, Home: 5:30pm-7:30am, Work: 8:00am – 5:00pm
V2G Control Strategies Need To Be Developed

- Battery needs to be first topped off to provide maximum swing. SOC is expected to be low when arriving.
- Lower/upper bounds need to be set by customer and communicated to grid-operator (impact to resource size).
- Integral of regulation up/down may not be zero during duration of service (home/work) leading to drainage of battery. Normalization of regulation up/down with zero energy exchange required.
Workshop Questions

Where are the major inefficiencies and losses in the power system (excl. generation and end-use)?

- Insufficient load participation in ancillary services
  - Operationally, load resources are much faster responding to contingencies than generators
  - Economically, loads can be cost effective
- Low utilization of entire electric infrastructure
  - 50% for the generation *
  - <50% for T&D

* EIA, for 2006. Total generation 4096 TWh, total capacity: 930 GW
How Could the Grid of the Future Be Operated?

Transportation Sector
What are breakthroughs are needed?

- Low cost electric energy storage
- New control paradigms (migration from central control to hybrid central/distributed control)
  - Integration into Microgrid
- New analytical tools for complex infrastructure development

What are the enabling technologies

- Ubiquitous communications
Additional Slides