Harnessing Demand Flexibility to Match Renewable Production

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Mahdi Kefayati and Ross Baldick

THE UNIVERSITY OF TEXAS AT AUSTIN
ELECTRICAL & COMPUTER ENGINEERING

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Agenda

1. Introduction and Motivation

2. Analysis of PEV Demand Flexibility

3. Localized Policies for Managing PEV Demand

4. Conclusion
Demand has been typically treated as inelastic and uncontrollable.

*Uncontrollable* generation is often incorporated with demand as “net-load”.

Substantial amount of demand is flexible:
- It is not bound to a specific power trajectory,
- e.g. HVAC systems, heating and cooling, and PEV charging,
- Usually a definite amount of energy should be delivered subject to a deadline and potentially rate constraints.
Paradigm Shift in Power Systems

- As the amount of non-dispatchable generation increases, we need more control on the demand side for reliable operation of the system.
- Depart from paradigm that controllable generation matches uncontrollable demand.
  - Controllable assets can be on supply side, demand side or even both.
  - This shift has market implications, particularly regarding how we distribute the cost of reserves necessitated by uncontrollable generation.
- Smart grids are the right step in providing the infrastructure for communication and control of demand side resources.
- A key challenge is the distributed and variable nature of demand side assets.
Our Focus

- How to efficiently harness demand flexibility to ease renewable integration.
- Key questions:
  - How much is the potential?
  - How hard is it to utilize demand flexibility?
  - How to incentivize demand participation?
- Our focus in this talk is mostly on PEVs, though some of the methods proposed can be used for other flexible loads.
For this analysis, we have used *Traffic Choices Survey* data from NREL [nre], \( \sim 450 \) vehicles, more than a year of GPS location data, \( \sim 725,000 \) trips, collected in Seattle, WA.

Wind and electric demand data are from ERCOT, January through November, 2010.

PEV parameters for calculating charging requirements are taken from Nissan Leaf specification:

- 70 miles range.
- \( C_d = 0.24 \)

For charging, Level 2 AC EVSE (3.3kW) is assumed.
So how flexible is PEV demand?

Let us first define demand flexibility:

$$\text{Flexibility} = 1 - \frac{\text{ Accumulated Energy Demand}}{\text{ EVSE Capacity } \times \text{ Dwell Time}}$$

- Basically, how much charging capacity can be left unused during dwell time.
- Between $-\infty$ and 1,
- Negative if inadequate dwell time,
- Zero if just enough,
- Approaches one as demand becomes more flexible.
Suitable Dwell Times for PEV Charging

- Not all dwell times are suitable for charging.
  - Short dwell times.
  - Where charging is not available.
  - The driver just does not like charging at that time.
- We consider only the dwell times that are longer than some threshold.
PEV Demand Flexibility vs. Min. Dwell Time

* Averaged over all trips, accumulating energy demand, EVSE Cap = 3.3kW.
What is the PEV demand if people start charging at the nominal EVSE rating once they arrive at their destination?
- also known as immediate mode.

This would naturally happen in absence of:
- Information, e.g. departure time.
- Incentives, e.g. tariffs.
- Demand management/Load Aggregation mechanisms.

Our analysis shows that:
- The aggregate load can be very correlated with current demand, exacerbating the diurnal patterns of the total load.
- High Peak-to-Average Ratios (PAR) can affect distribution network, even though the aggregate PEV load might be relatively small compared to total load.
- Clustering is indeed likely, e.g. Mueller area in Austin.
PEV Demand as Conventional Load

- **Immediate Charging**
- **ERCOT Net Load – No PEV**
- **Net Load @ 10% PEV Penetration**
- **Net Load @ 40% PEV Penetration**
- **Net Load @ 70% PEV Penetration**

- **Min dwell time = 3hrs, ERCOT data is average over days in 2010.**
- **Total number of vehicles = 15M (Total number of vehicles registered in TX).**
- **40% penetration rate is assumed.**

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Harnessing Demand Flexibility
Some PEVs support delayed mode.

In delayed mode, the PEV owner is required to enter his/her departure time.

The PEV automatically starts at the latest time possible to finish charging before the departure time.

The PEV is charged at the full charging rate.

The charging profile is similar to immediate mode, except that is shifted to the end of the dwell time.

Our analysis shows that:

- Delayed charging can actually be worse than immediate mode in terms of correlation with demand.
- High Peak-to-Average Ratios (PAR) can affect distribution network, even though the aggregate PEV load might be relatively small compared to total load.
PEV Demand with Delayed Charging

- **Min dwell time = 3hrs, ERCOT data is average over days in 2010.**
- **Total number of vehicles = 15M (Total number of vehicles registered in TX).**
- **40% penetration rate is assumed.**
The Average Rate Policy

- Consider the *Average Rate (AR)* policy:
  - Upon arrival, ask the driver for departure time.
  - Charge at the minimum of EVSE capacity and energy demand divided by dwell time.
  - That is, pick the rate such that the dwell time is just enough to finish the charging, subject to EVSE capacity.

Charge rate:  \[ x_t = \min\left\{ \frac{d}{t_d - t_a}, \bar{x} \right\} \]  

- Requires no information/incentives about prices and/or network status.
- Achieves full charge by departure time if possible.
PEV Load vs. Wind

- Average Rate Policy
- Immediate Charging
- Delayed Charging
- ERCOT Wind
- ERCOT Net Load
PEV Load - Only Home Charging

Average Total PEV Demand [GW]

Time of Day [h]

Average Rate Policy @ Home
Immediate Charging @ Home
Delayed Charging @ Home
ERCOT Wind
ERCOT Net Load
Average Rate Policy - Analysis

- Advantages:
  - Much smoother local and aggregate load.
  - Much better correlation with renewables.
  - Battery spends less time in high SoC $\rightarrow$ longer battery life.
  - No need for communication and control.
  - No sacrifice of user comfort.
  - Can be readily implemented in current PEVs (perhaps via a software update).

- Can we utilize flexibility even more?
  - Need for more information (e.g. market prices, frequency deviations).
  - Need for incentives for users (dynamic prices, incentives).

- What can be attained?
  - Actual demand response and coordination with the grid.
  - Provision of ancillary services (AS).
  - See [KefCar10] and [KefBal11] for more discussion.
Utilizing demand flexibility is key for effective integration of intermittent renewables.

PEV load is particularly flexible.

Local information can help substantially in matching PEV load with renewables and reduce network burden.
References

Energy delivery transaction pricing for flexible electrical loads.
In *2011 IEEE International Conference on Smart Grid Communications (SmartGridComm)*, pages 363–368, Brussels, Belgium, October 2011.

Efficient energy delivery management for PHEVs.
In *2010 IEEE International Conference on Smart Grid Communications (SmartGridComm)*, pages 525–530, Gaithersburg, MD, October 2010.

[nre] NREL Secure Transportation Data Project.