Harnessing Demand Flexibility to Match Renewable Production

50th Annual Allerton Conference on Communication, Control, and Computing

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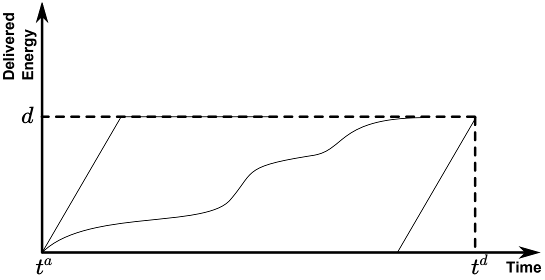
Allerton, IL, Oct, 3, 2012

Agenda

Flexibility of Electric Demand

- 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

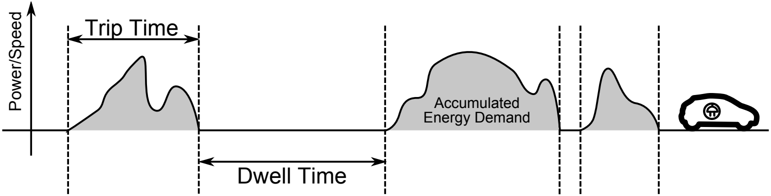
- As the amount of non-dispatchable generation increases, we need more control on the demand side for reliable operation of the system.
- Depart from paradigm that controllable generation matches uncontrollable demand.
  - Controllable assets can be on supply side, demand side or even both.
  - This 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.

PEV Demand

- For this analysis, we have used *Traffic Choices Survey* data from NREL [nre], ~ 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.



PEV Demand Flexibility

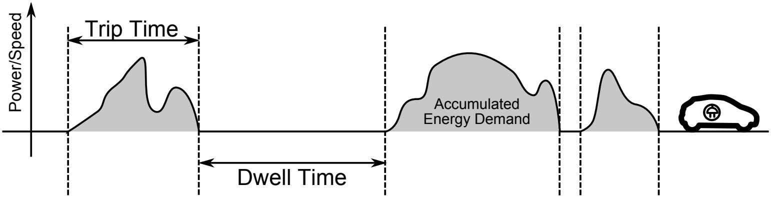
- So how flexible is PEV demand?
- Let us first define demand flexibility:

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

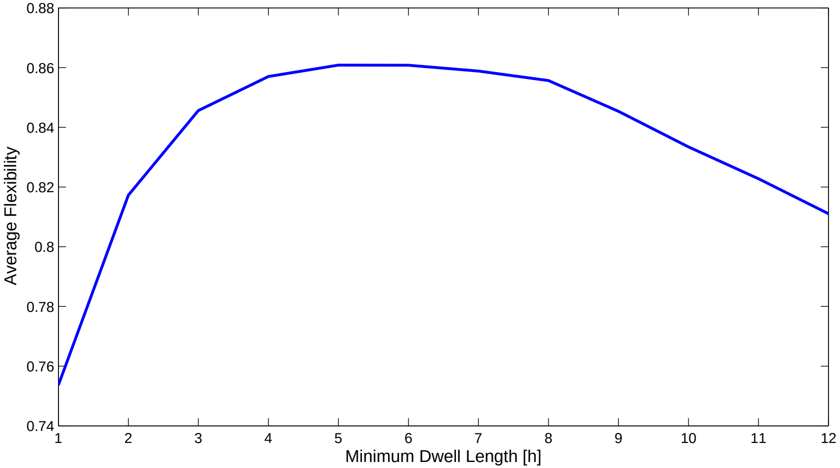
  - Basically, how much charging capacity can be left unused during dwell time.
  - Between $-\infty$ and 1,
  - Negative if inadequate dwell time,
  - Zero if just enough,
  - Approaches one as demand becomes more flexible.

Suitable Dwells 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

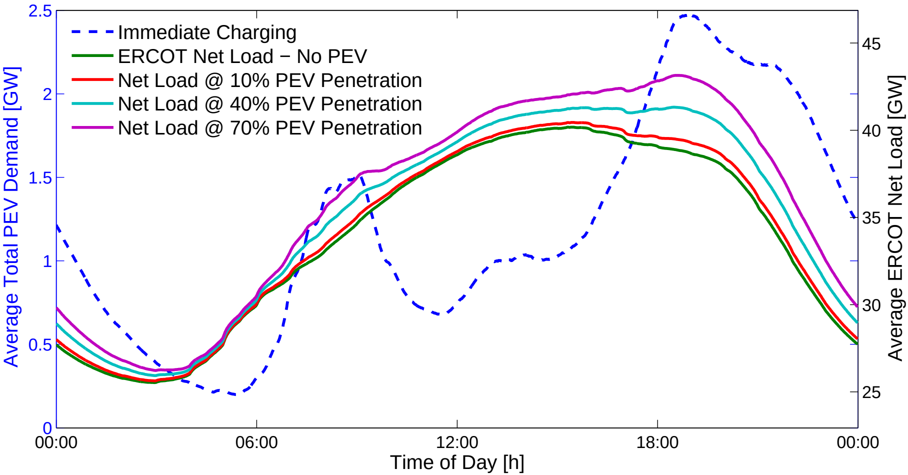


* Averaged over all trips, accumulating energy demand, EVSE Cap = 3.3kW.

PEV Demand as Conventional Load

- 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

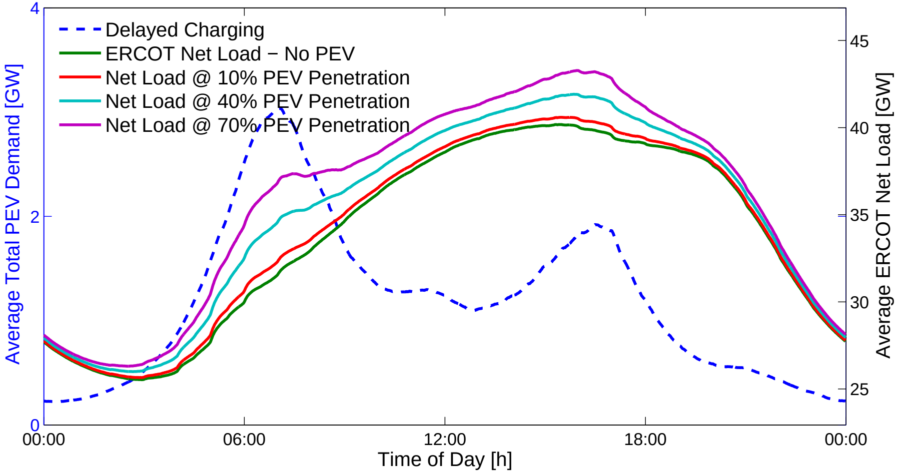


- Min dwell time = 3hrs, ERCOT data is average over days in 2010.
- Total number of vehicles = 15M (Total number of vehicles registered in TX).
- 40% penetration rate is assumed.

PEV Demand with Delayed Charging

- 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.

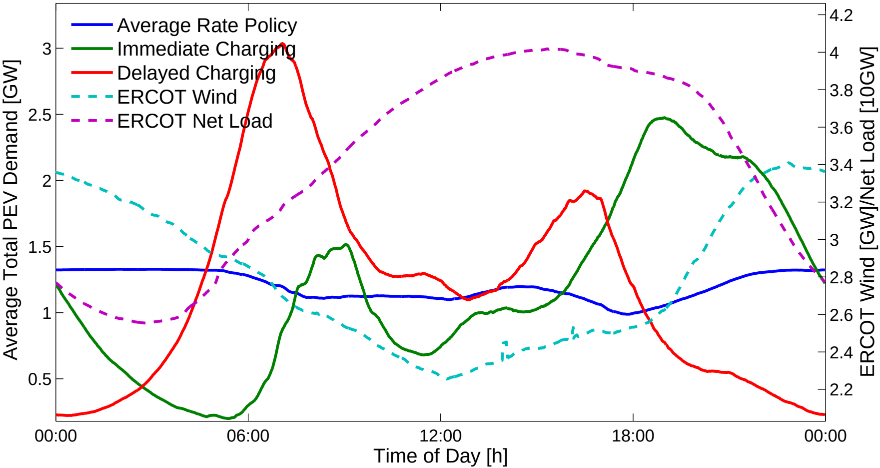
The Average Rate Policy

- 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.

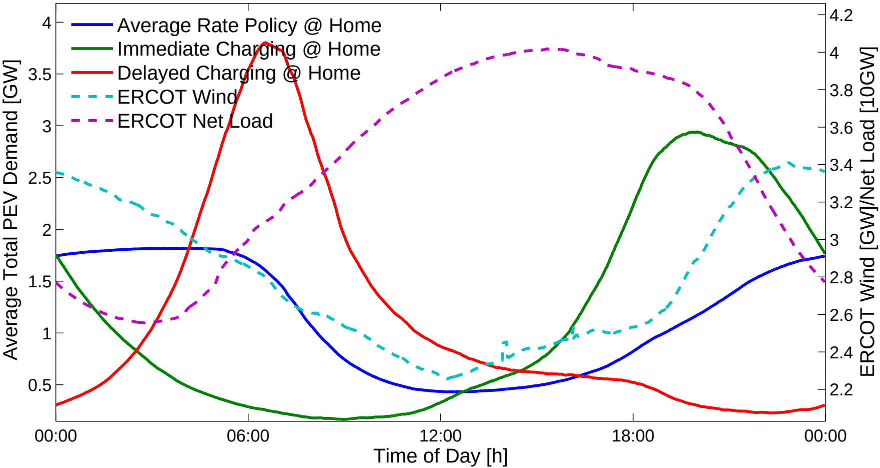
$$\text{Charge rate:} \qquad x_t = \min\{\frac{d}{t^d - t^a}, \bar{x}\} \tag{1}$$

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

PEV Load vs. Wind



PEV Load - Only Home Charging



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.

Conclusion

- 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

[KefBal11] Mahdi Kefayati and Ross Baldick.
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In *2011 IEEE International Conference on Smart Grid Communications (SmartGridComm)*, pages 363–368, Brussels, Belgium, October 2011.

[KefCar10] M. Kefayati and C. Caramanis.
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[nre] NREL Secure Transportation Data Project.
http://www.nrel.gov/vehiclesandfuels/secure_transportation_data.html.