A Framework for Investigating the Impact of PEV Charging on Distribution Systems with the Integrated Modeling and Simulation of Transportation Network

Wencong Su, Ph.D.
Assistant Professor
Department of Electrical and Computer Engineering
University of Michigan-Dearborn
E-mail: wencong@umich.edu
Web: www.SuWencong.com
Transportation sector consumes 1/3 of total energy in U.S.A.

Current U.S. vehicle fleet = ~250 millions vehicles

Getting charged up about a gasoline-free future!

(2013 IEEE Industrial Electronics Society Student Best Paper Award)
Plug-in Electric Vehicles are coming!!!

Projected Plug-in Vehicle Market Share

- 1 Million PHEVs/PEVs on the road by 2015
- 425,000 PHEVs/PEVs will be sold in 2015
- 2.5% of all new vehicle sales in 2015
- 62% of the entire US vehicle fleet by 2050

10% market share of PHEVs/PEVs

~10kW charging level

250 million vehicles

X 10%

X 10kW

250 GW

1,000 GW (total U.S. installed generation capacity)
Study effects of the aggregate behavior of PEV charging loads on power grids

Simulate the aggregate peak demand under various charging scenarios

Estimate the aggregate PEV traffic demand, driving behavior, and traffic pattern

(1) When would PEVs (time) start to be recharged?
(2) How much electrical energy (kWh) is needed to charge PEVs?
(3) What level of charge (kW) is needed at each time step?
National Household Travel Survey (NHTS) Dataset:
The data are **NOT** ideal for devising a detailed city or regional level model of the driving habits by analyzing a **statewide and nationwide** dataset.

UC Davis Institute for Transportation Studies:
The data are ideal for giving a general sense of how consumers prefer to charge their vehicles, but are **NOT** usable for detailed analysis of charging behavior.

Vehicle Testing Data from Idaho National Laboratory:
The data are useful for deducing the general characteristics and fuel efficiency of different vehicles, but are **NOT** useful for detailed analysis.

Plug-in Hybrid and US Light Vehicle Data from DOE:
The data are useful for getting a general idea of the characteristics and fuel efficiency of different vehicles, but are **NOT** useful for detailed analysis.
Evaluate the **localized** impacts of PEV charging to utility distribution systems

Capture and simulate the **individual** PEV charging load demand

Need a micro-level analysis incorporating **spatial** and **temporal** information

- ~10,000 square miles
- 40,000 links
- 14,000 intersections
- 9 million residents
- ~26.5 million vehicle trips
- ~1.5 million transit trips
- 500,000 concurrent drivers

Individual travel:
- Trip based
- Activity based

Transportation scenarios:
- Price based (e.g., add toll at the selected road)
- Time based (e.g., flexible working hours)
- Control based (e.g., signal control and ramp metering)

Sioux Falls, South Dakota, Transportation Network

Coupled Power Distribution and Transportation Networks
A micro-level analysis incorporating **spatial** and **temporal** information

**Data Estimation from Public Survey**
- Battery size and all electric range
- Charging level
- PEV population type

**Data Generated from the Transportation Simulator includes**
- Vehicle driving and routing patterns
- Parking time
- Vehicle density at any node/link at any time
- Trip distance of any vehicle

**Co-Modeling Interface**
- GIS Information

**Co-Simulation and Co-Optimization**

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Power System Scenarios:
- Base load demand on weekday, weekend, holiday
- PEV charging scheme
- ......

Transportation Scenarios:
- Price based (e.g., add toll at the selected road)
- Time based (e.g., flexible working hours)
- Control based (e.g. signal control and ramp metering)
- ......

Deterministic Analysis:
- System-level analysis under different scenarios
- Component-level analysis (component ability to supply PEV charging load) under different scenarios

Stochastic Analysis:
- Stochastic simulations (Monte Carlo) over a full day/week/year
- General conclusions concerning likely distribution system impacts