UNIVERSITY OF MICHIGAN-DEARBORN

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

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Transportation sector consumes 1/3 of total energy in U.S.A.

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

Getting charged up about a gasoline-free future!

[1] **W. Su**, H. Rahimi-Eichi, W. Zeng, and M.-Y. Chow, "A Survey on the Electrification of Transportation in a Smart Grid Environment," *IEEE Trans. on Industrial Informatics*, vol.8, no.1, pp.1-10, Feb. 2012.
(2013 IEEE Industrial Electronics Society Student Best Paper Award)

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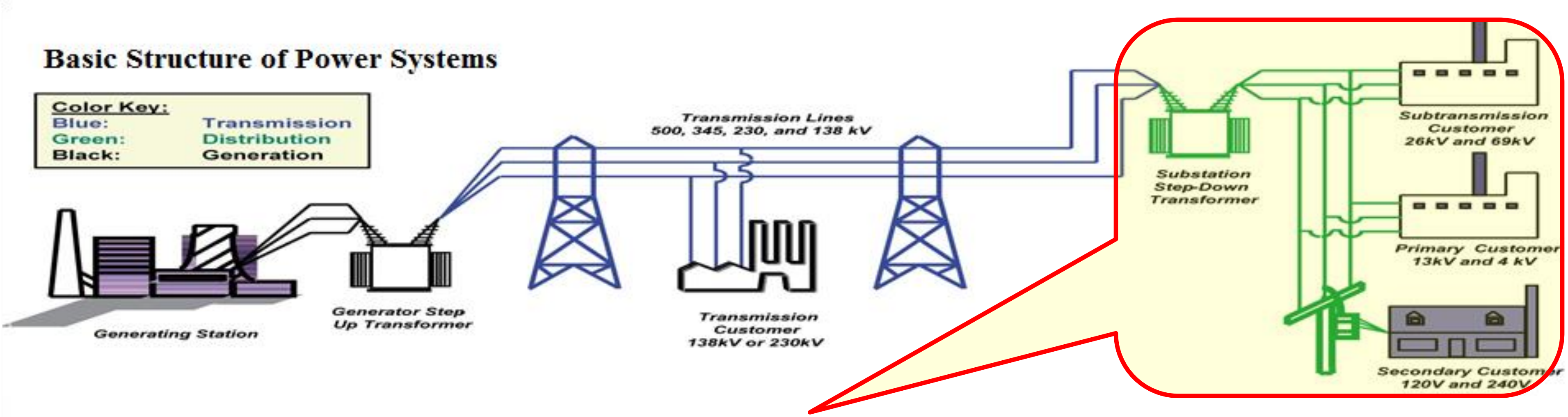
1 Million	PHEVs/PEVs on the road by	2015
425000	PHEVs/PEVs will be sold in	2015
2.5%	of all new vehicle sales in	2015
62%	of the entire US vehicle fleet by	2050

Projected Plug-in Vehicle Market Share

Plug-in Electric Vehicles are coming !!!

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.

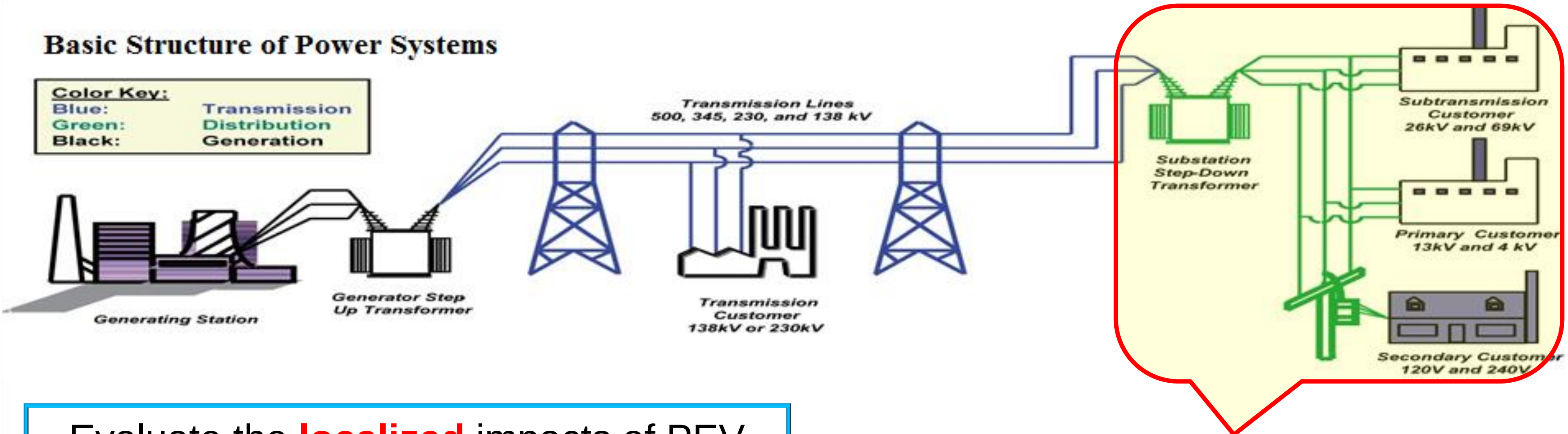
Vehicle Testing Data from Idaho National Laboratory:

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.

AK = Alaska	253
AL = Alabama	425
AR = Arkansas	258
AZ = Arizona	7,157
CA = California	21,225
CO = Colorado	306
CT = Connecticut	275
DC = District of Columbia	264
DE = Delaware	245
FL = Florida	15,884
GA = Georgia	7,502
HI = Hawaii	254
IA = Iowa	3,752
ID = Idaho	259
IL = Illinois	809
IN = Indiana	3,458
KS = Kansas	263
KY = Kentucky	271
LA = Louisiana	292
MA = Massachusetts	412
MD = Maryland	355
ME = Maine	277
MI = Michigan	643
MN = Minnesota	340
MO = Missouri	389
MS = Mississippi	257
MT = Montana	256
NC = North Carolina	11,096
ND = North Dakota	256
NE = Nebraska	1,289
NH = New Hampshire	254
NJ = New Jersey	559
NM = New Mexico	251
NV = Nevada	256
NY = New York	16,165
OH = Ohio	724



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

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"Dynamic Network Assignment-Simulation Model" [1]
Regional Transportation Simulation Tool for Evacuation Planning (RTSTEP) [2]

- ~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

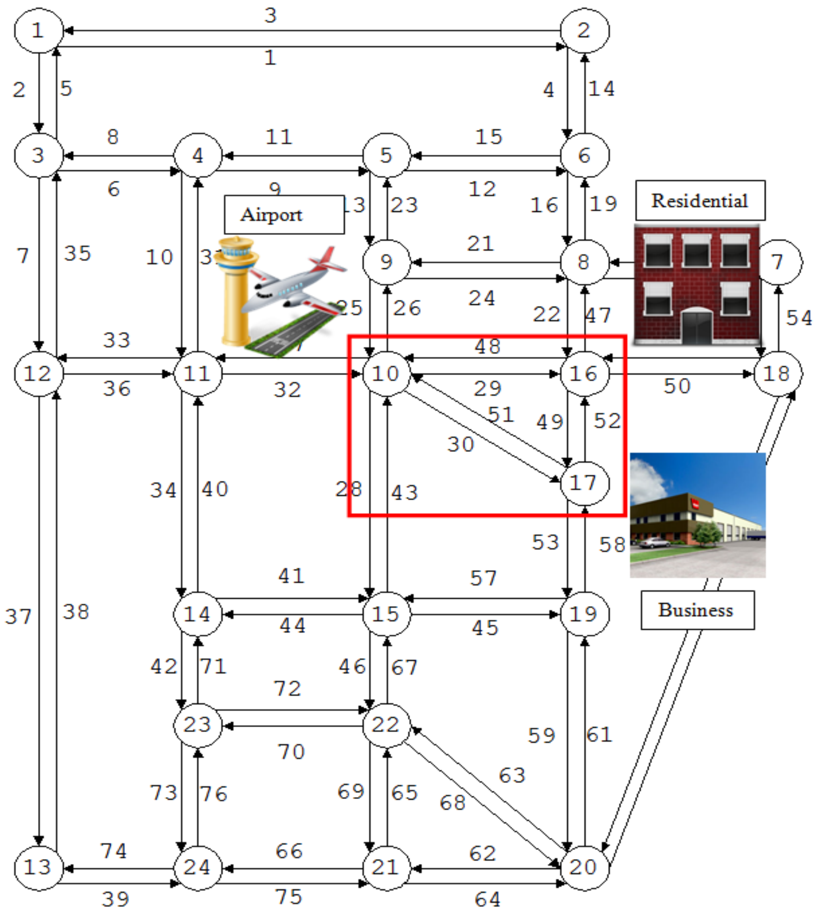
Individual travel:

- ❑ Trip based
- ❑ Activity based

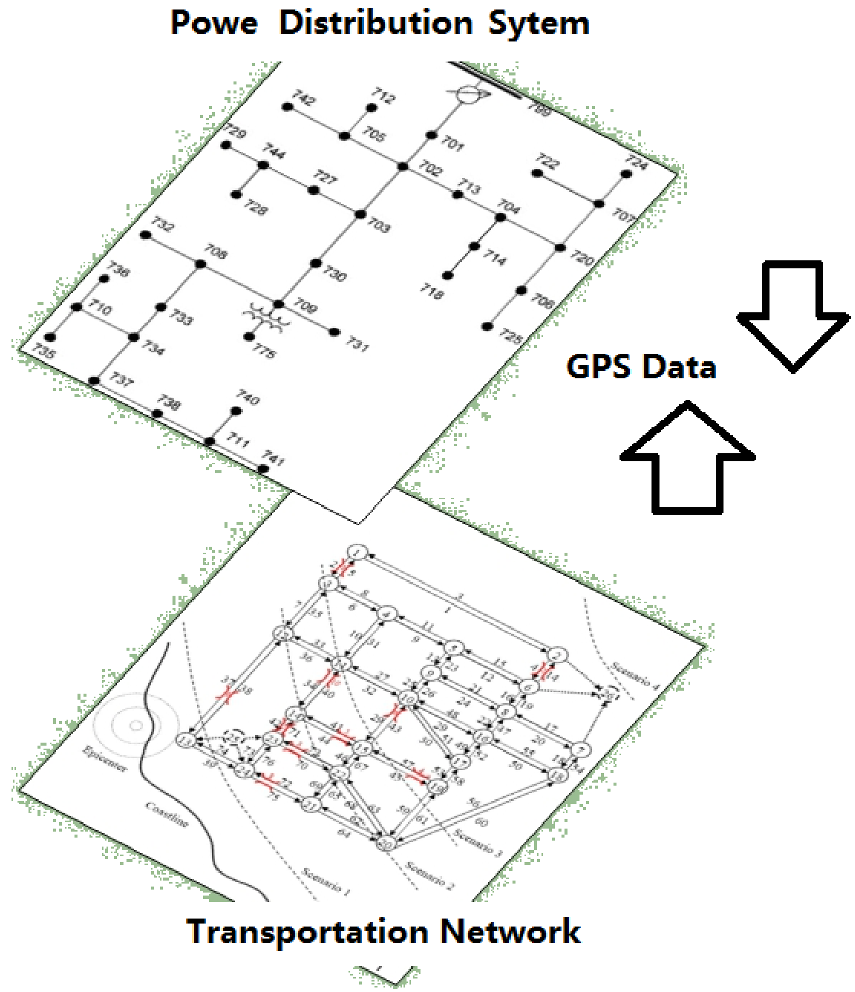
Transportation scenarios:

- ❑ 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)

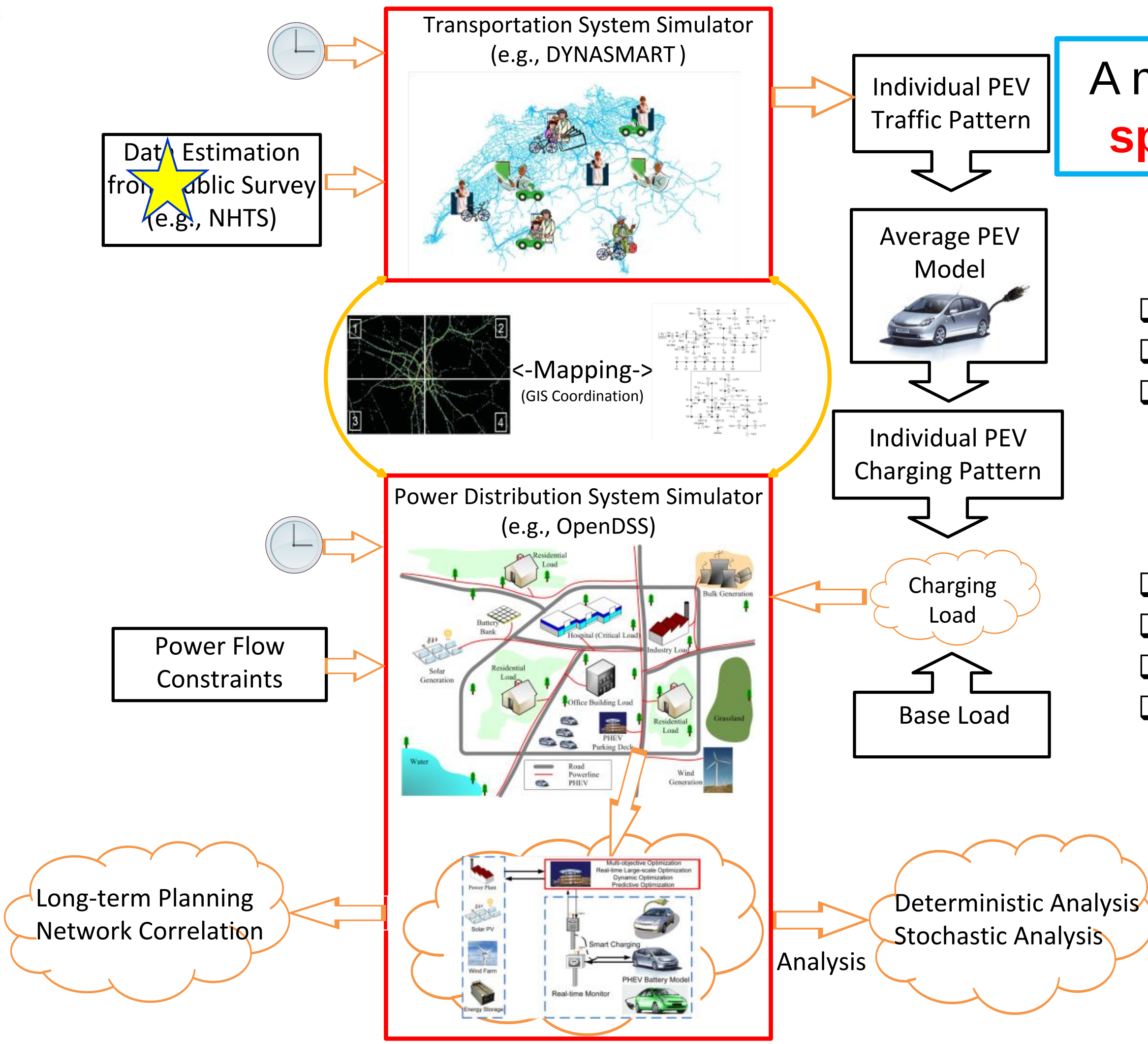
[1] X. Zhou, H.S. Mahmassani, and K. Zhang, "Dynamic Micro-Assignment Modeling Approach for Integrated Multimodal Urban Corridor Management," *Transportation Research Part C*, Vol. 16, pp 167-186, 2008.
[2] Transportation Research and Analysis Computing Center, Argonne National Laboratory. [Online] http://www.ntis.gov/search/product.aspx?ABBR=DE20121033873



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

[1] **W. Su**, J. Wang, K. Zhang, and M.-Y. Chow, "Framework for Investigating the Impact of PHEV Charging on Power Distribution and Transportation Networks," in *Proc. of the 38th IES Annual Conference*, Montreal, Canada, Oct. 25-28, 2012.

[2] **W. Su**, and K. Zhang, "Investigating the Impact of PEV Charging on Power Distribution System with the Integrated Modeling and Simulation of Transportation Network, 2013. (in preparation)

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