Dynamic Wireless V2X Opportunities for Future Power Distribution Systems

Stanley and Karen Pigman College of Engineering

Donovin Lewis, *GSMIEEE*, and Dan M. Ionel, Ph.D., *FIEEE*

SPARK Laboratory
PEIK Power and Energy Institute of Kentucky

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Introduction and Major Contributions

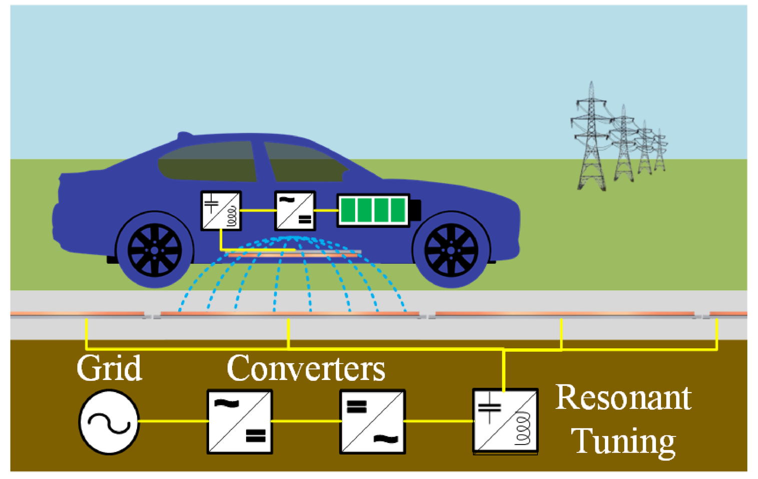
- Two methods are developed for the modeling of electric vehicles (EVs) as energy storage considering efficiency and user behavior
- Proposed models can be used to explore methods of grid or emergency support after extreme weather events or outages
- An example case study is provided for the utilization of a fleet of vehicles in a residential neighborhood to provide localized support.

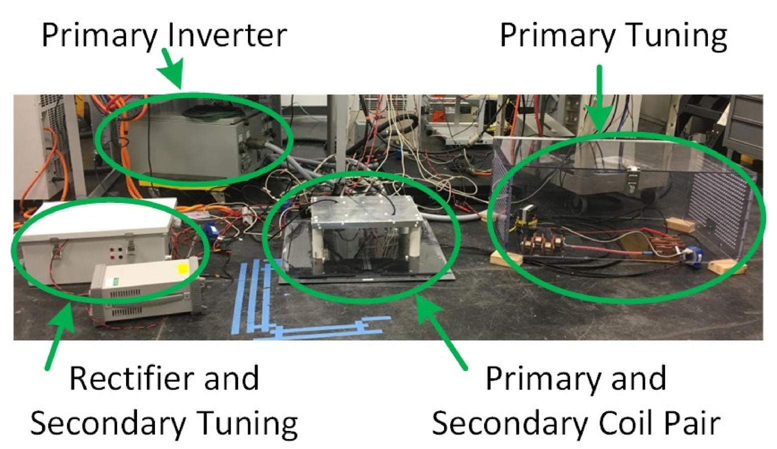
Energy Storage Operation using Available EVs

- The temporal mismatch between renewably generated energy availability and peak electricity demand could led to large periods of unmet demand due to the variability of weather-based resources
- Areas with high renewable penetration benefit from the integration of accompany energy storage but suffer from high costs of implementation and the need for specialized systems
- The cost of residential storage can be offset by using EVs with V2X capability, benefitting from low urban battery capacity utilization
- The contribution of energy storage can be modeled depending on the imbalance between renewable energy and load demand.

$$P_{imb}(t) = P_{gen}(t) - P_{dem}(t) \qquad E_{ES}(t) = \eta_{sd} * E_{ES}(t-1) + P_{ES}(t)\Delta t$$

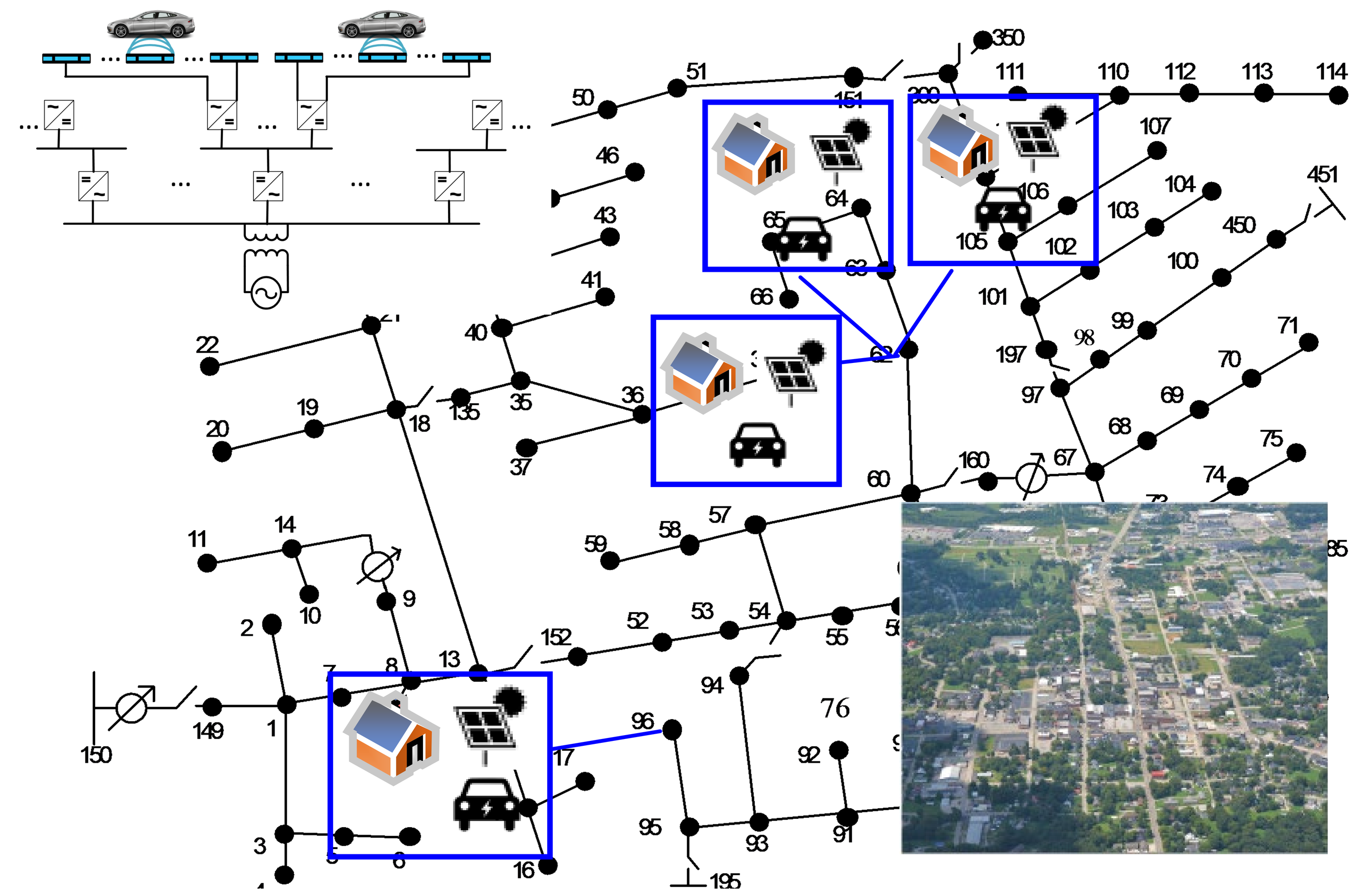
$$P_{ES}(t) = \begin{cases} P_{ES}/\eta_d & P_{ES} > 0 \\ \eta_c * P_{ES} & P_{ES} < 0 \end{cases} \qquad E_{EV}(t) = \begin{cases} E_{EV} & t \le t_d \;\mid\; t \ge t_a \\ 0 & t_d < t < t_a \end{cases}$$





Dynamic Wireless Charging for Maximal EV Availability

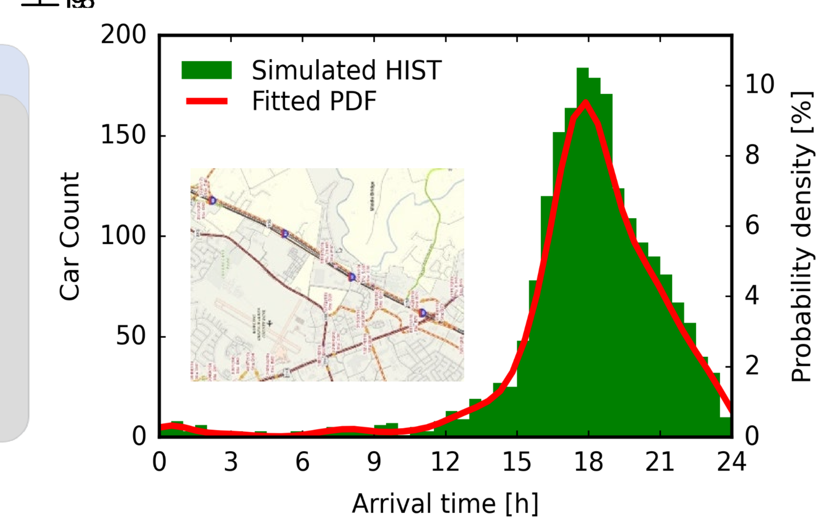
- Dynamic wireless charging systems (DWCS) allow for charging and discharging of vehicles in-motion with electromagnetic coupling
- Energy can be provided at full roadway speed with control by grid-side power electronics in response to roadway traffic behavior with efficiencies greater than 92% for high power (50-200kW)
- Widescale implementation could reduce battery capacity requirements or enable self-sustaining operation
- New developments include the capability to transmit over a sizable airgap of 8 inches with high-frequency operation (80-90kHz)
- Experimental public roads are under development in several states (Utah, Indiana, Michigan) and countries (France, Italy, Germany)
- The capability to connect in-route allows for near continuous EV availability for local grid support or renewably supplied charging.

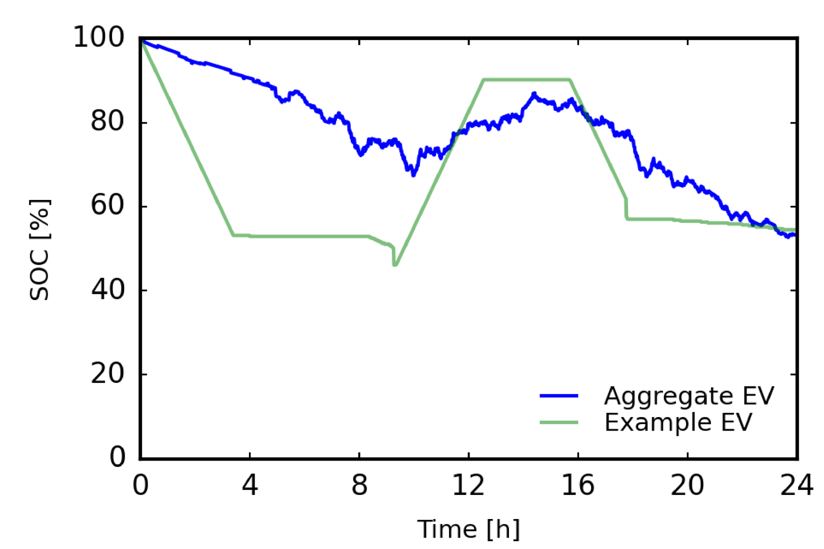


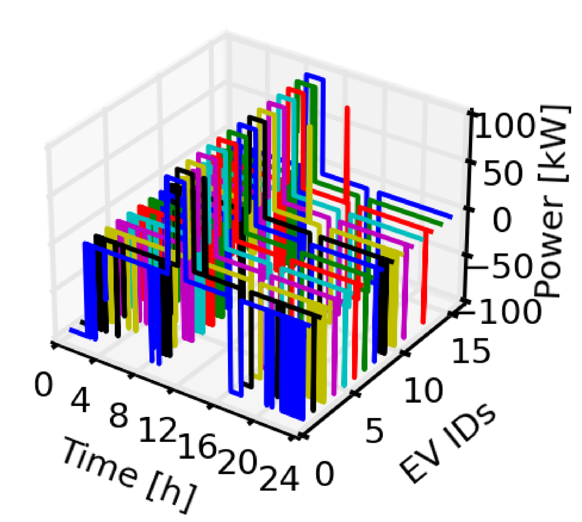
ESS
- Rated Energy
- Rated Power
- Efficiency
- Self-discharge

Goal: Fulfill demand with a defined generation-load

V2G
- Availability
- Usable Battery %
- Trip Energy Usage
- Energy Capacity Distribution
- Charger Power Distribution





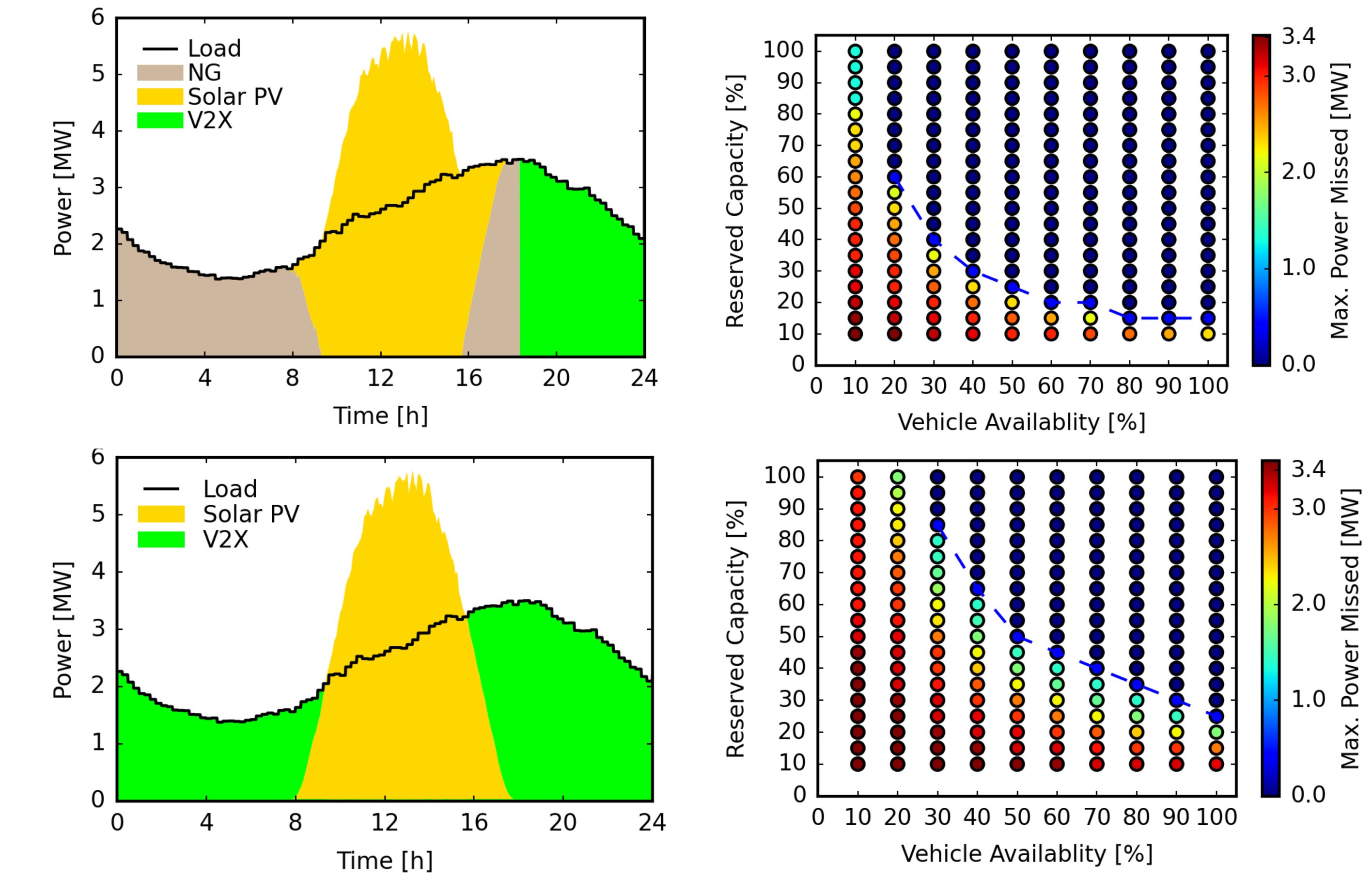


Energy Storage Modeling – Aggregate and Distributed

- Two methods are developed and explored for modeling electric vehicle energy storage at the residential-level:

1. An aggregate model considering a collection of EVs as a cluster with a bulk efficiency loss and availability
2. A distributed model with EVs clustered depending on travel behavior and considering individual charging power

- The aggregate energy storage model is a conventional approach and assumes approximately ideal V2X operation for dispatch
- The method of distributed dispatch proposed can instantiate any number of EVs with their own capacities, travel behavior, and reserved state of charge (SOC) with independent operation
- Publicly available travel behavior can allow for the creation of large distributions sampled for individual EVs
- The trade-off is computational efficiency and accuracy with simplifications in development for the multi-agent methodology.



Top- Electric vehicle dispatch following extreme weather event
Bottom- Electric vehicle dispatch following day-long outage

Case Study – V2X for IEEE Distribution Resiliency After Extreme Weather Event

- Two case studies were performed: one assuming extreme weather at peak load and another with a day-long outage
- A residential neighborhood like the IEEE 123 bus test feeder with 1700 homes and an assumed 2000 cars
- Residential load was derived from experimental smart meter profiles for 5000 homes from the SET project in Glasgow, KY
- Electric vehicles were assumed to have 80kWh capacity with 11kW V2X charging capability at home and work
- Parametric sweeps were implemented for reserved energy capacity for V2X support and electric vehicle availability.

Conclusions

- The results of the case study indicate the potential grid support from interconnected EVs with varying user willingness
- Higher vehicle availability, like that supported by DWCS, can cover power/demand deficit at a lower energy capacity Proposed models could be used for distribution planning studies including incentives for V2X capable chargers.
- Future work will include the development of metrics to compare between aggregate and distributed case considering overall cost of investment.

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