IEEE PES Power & Energy Society®

2022 IEEE PES T&D Poster Competition

Grid Impact Studies for Dynamic Wireless Charging of Moving Electric Vehicles

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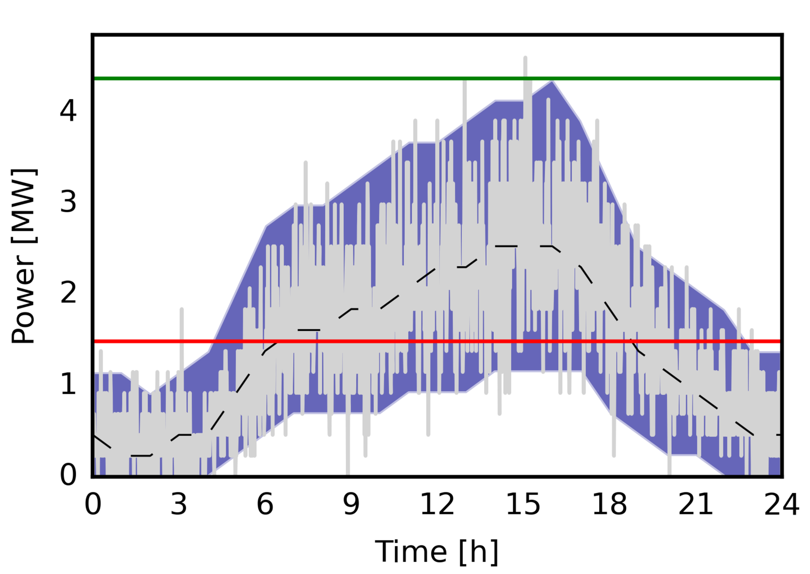
Introduction and Major Contributions

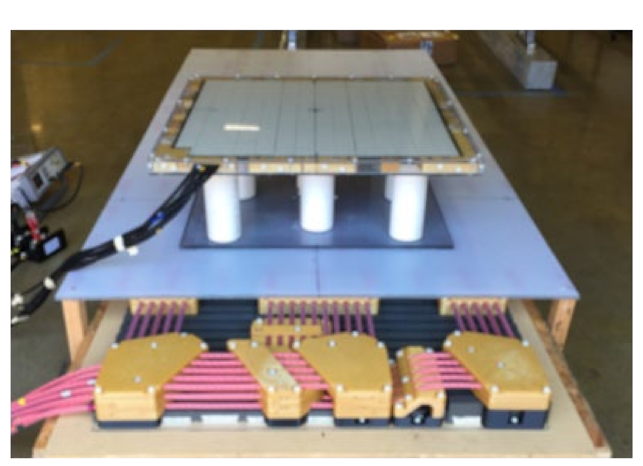
- Parametric studies for accurate load modeling considering location-specific traffic behavior for dynamic wireless charging (DWCS) of electric vehicles (EV) on a roadway
- Power electronic control compensation for highly variable demand, assuming 100% user uptake, independent on the number and speed of vehicles

Dynamic Wireless Charging Traffic Load Simulation

- DWCS provide electricity to EVs in motion at full roadway speed using electromagnetic coupling
- DWCS power demand is controlled by grid-side power electronics in response to vehicle traffic behavior on the roadway
- Due to the traffic dependency, system load is heavily dependent on vehicle speed, number, and the size of the system, varying greatly at the MW-level and can be modeled using:
  - Poisson Distribution interpolation of the number of vehicles arriving per defined time step
  - Normal Distribution sampling for an assumed constant speed for the duration of roadway travel
- Python scripts were developed to emulate vehicles entering the roadway with a duration related to their initial speed and the length of the DWCS roadway section (1 mile)
- Parametric control of the traffic load model enables studies for reduced variation with control modification.

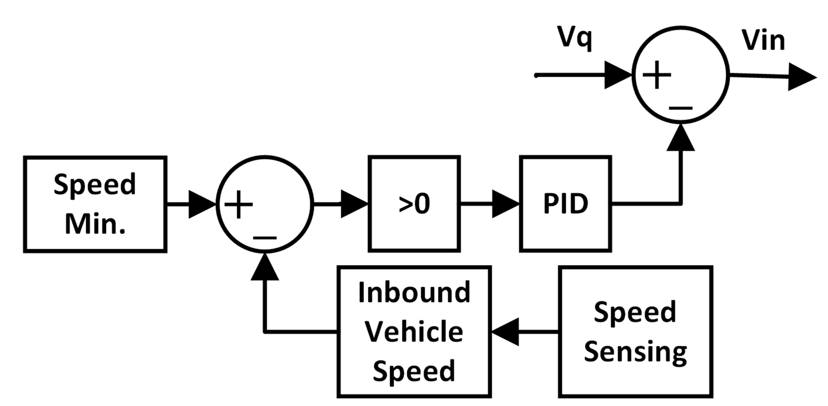
Left- Example DWCS load curve with 95% confidence interval
Right-Experimental Prototype for a wireless charging coil

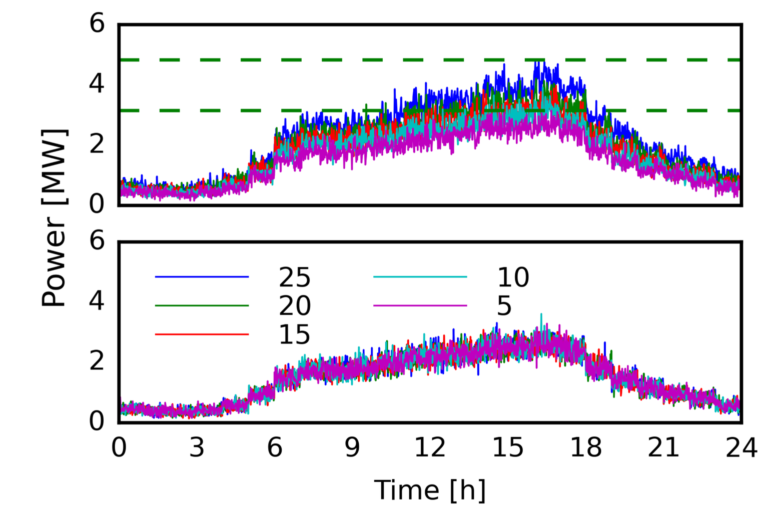


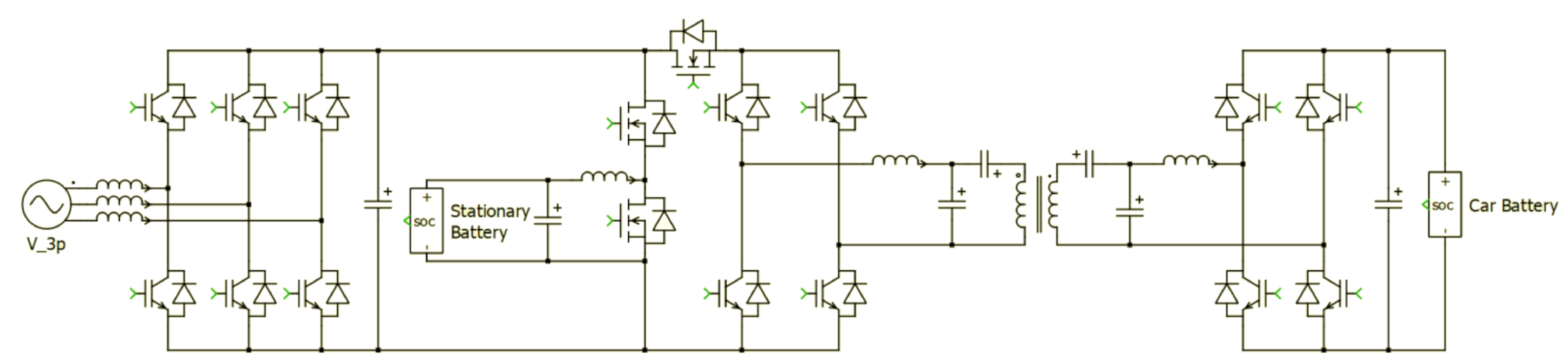


Traffic Speed Compensation

- Variability in the speed of traffic can greatly alter expected electric load due to the limited timing for energy transfer
- Slow drivers receive more energy and account for a higher load
- Increased speed variation can increase average and maximum power by 40% from the base speeds
- To compensate for driver choice, a control scheme is proposed to limit the energy transfer below a defined limit
- Variation in speed reduces by as much as 20-30% with speed control in a similar fashion to the proposed PID approach.

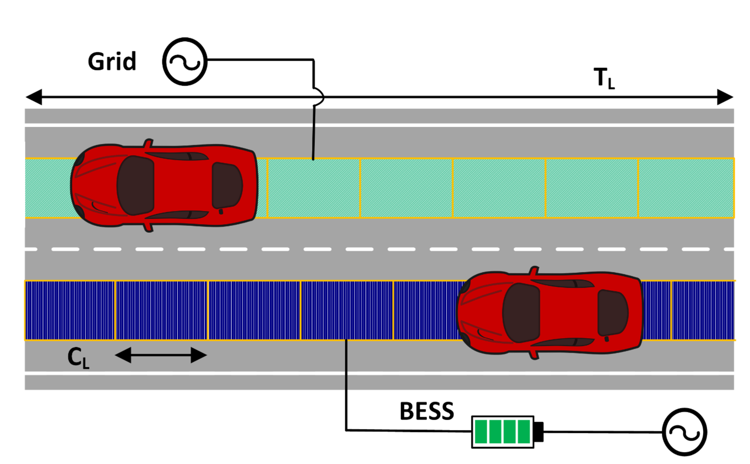


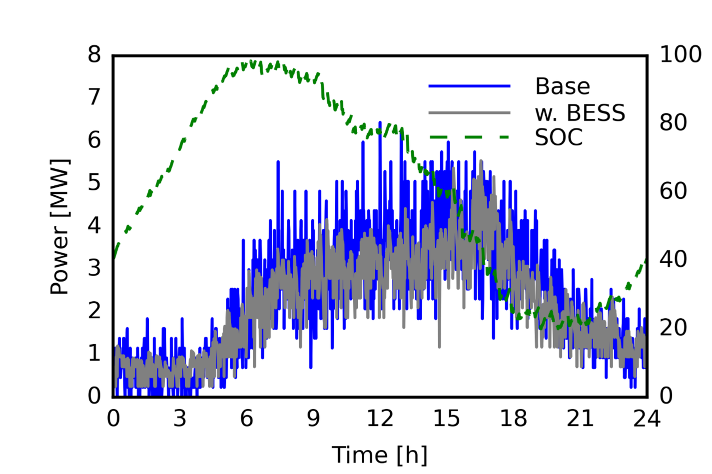


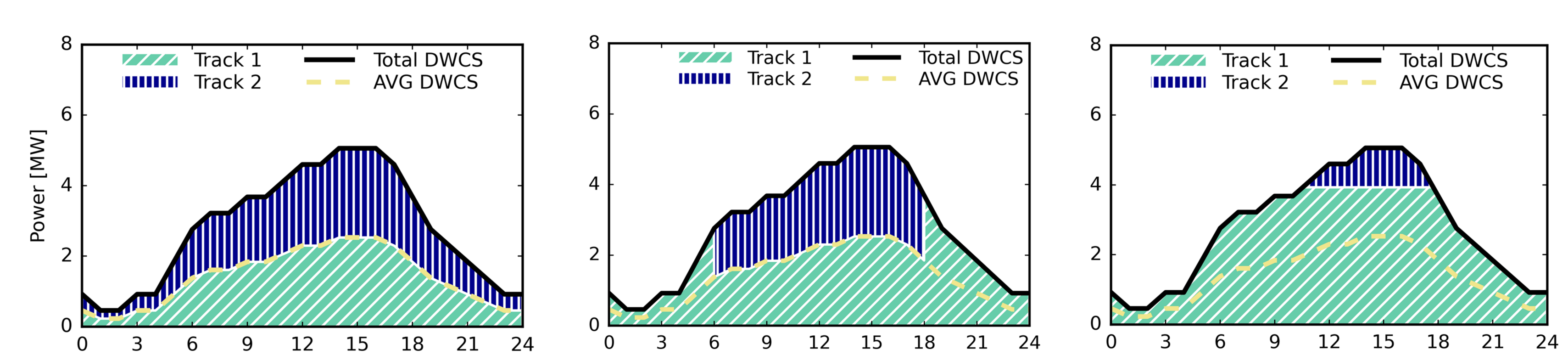


Traffic Density Compensation with Accurate Sensing

- The density of vehicles on the roadway can greatly increase load during peak hours and is affected by speed-related traffic jams
- The Annual Average Daily Travel (AADT) used in this study is provided by the Kentucky Transportation Cabinet with sensing along I-70 between Bowling Green, KY, and Nashville, TN
- High sensing resolution for traffic data is necessary to effectively capture variation of vehicles currently on the roadway
- High traffic density can be accounted for using integrated battery energy storage systems and shifting between lanes of a roadway as shown below in two potential methods:
  - Shifting based on peak demand time within the system
  - Allocating a defined capacity for peak shaving.
  - Ripple and variability can be reduced by 60 and 40% respectively



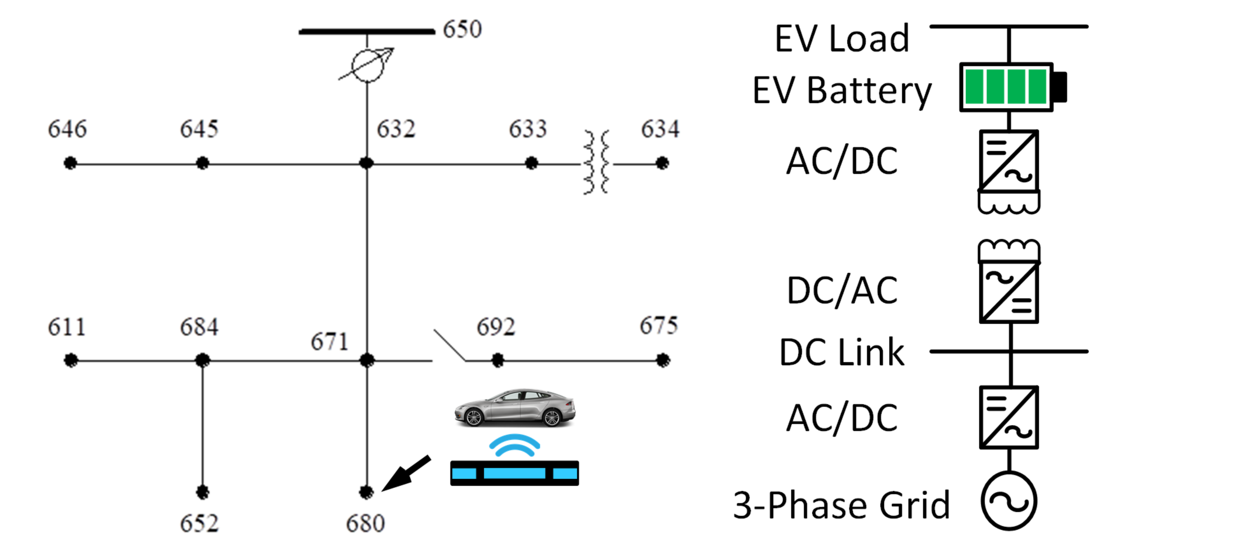




(a) (b) (c)

Case Study – Aggregate Load on IEEE Distribution

- OpenDSS by EPRI is employed as an electric power distribution system simulator to study DER grid integration
- A modified IEEE 13 bus distribution system was modeled with an added aggregated DWCS load scaled to and replacing the largest system load alongside residential load variation.
- Power flow solution with added DWCS showcases increased variability in voltage and power. Speed and traffic volume compensation reduces overall power system impact.



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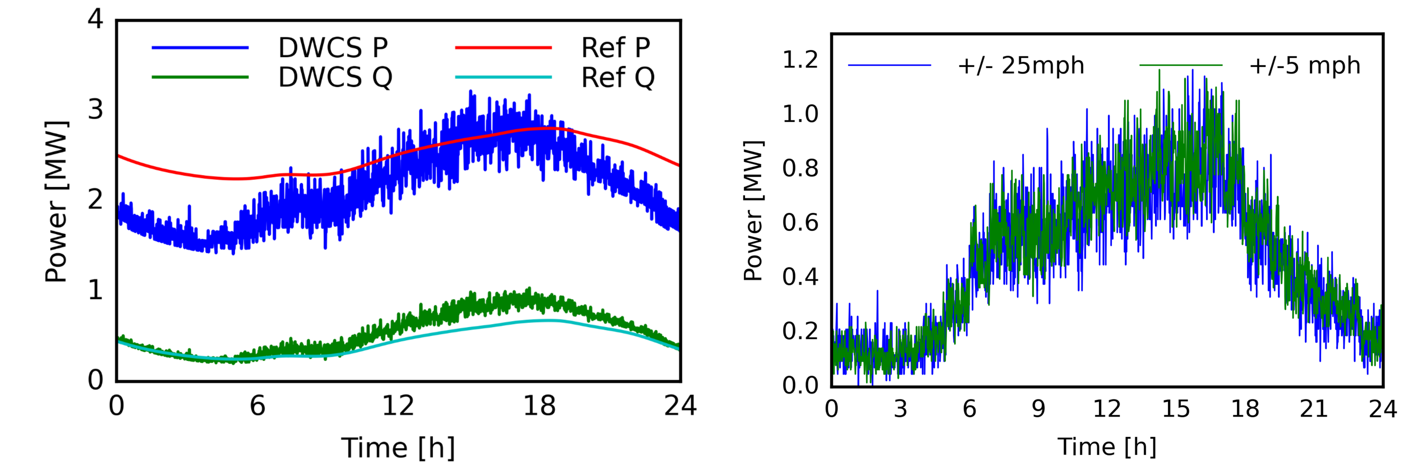

Conclusions

- Speed compensation can reduce maximum and average power variability by 20-30% with different speed mean and deviation
- Shifting or shaving of peak load demand may reduce power system impact of DWCS load without compensation and increase converter utilization by up to 50%.

Future and Ongoing Work

- Further developments concerning segmentation and feasible scalability of transmitting coils when connected to the larger power system
- Full implementation, simulation, and testing for the control of the switchable dynamic wireless charging coil with an integrated battery system.

Acknowledgement

This work was supported by the Otis A. Singletary Graduate Research Fellowship and the NSF Graduate Research Fellowship under Grant No. 1839289. Any findings and conclusions expressed herein are those of the authors and do not necessarily reflect the views of the NSF.