Charging Stations of the Future

What will define charging stations of the future?

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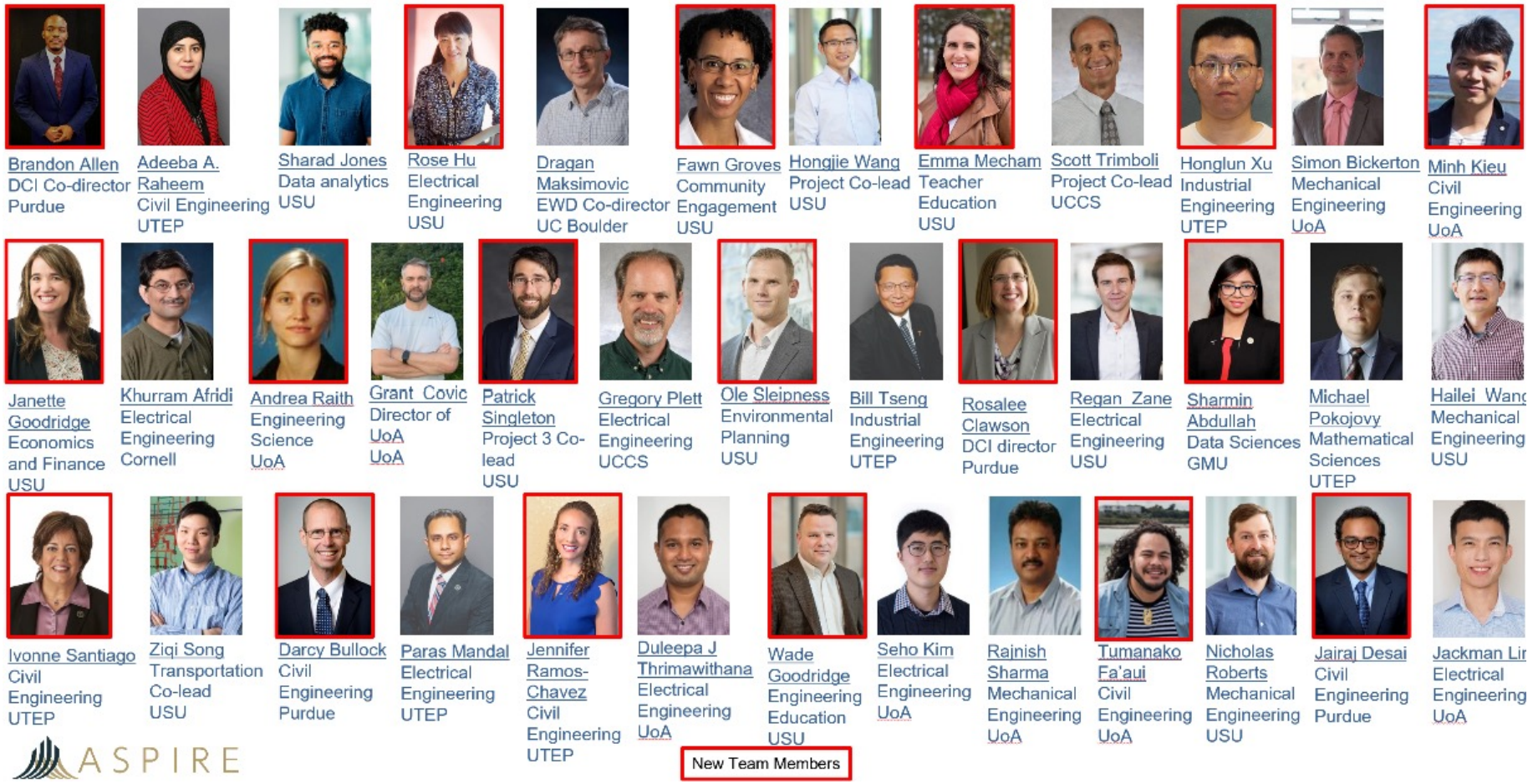
- Electrical Engineering
- Mechanical Engineering
- Industrial & System Engineering
- Civil Engineering
- Business
- Economics
- Marketing
- Social Science



Charging Stations of the Future

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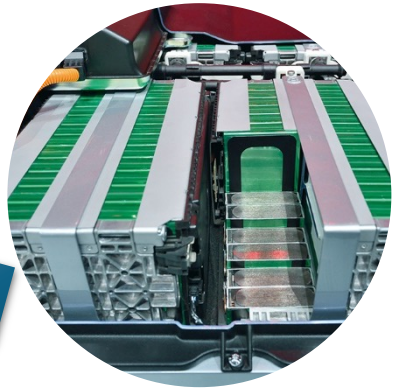

Battery Modeling & Control

High Power Charging

Charging Station Location, Economics, & Management

Battery Modeling & Control

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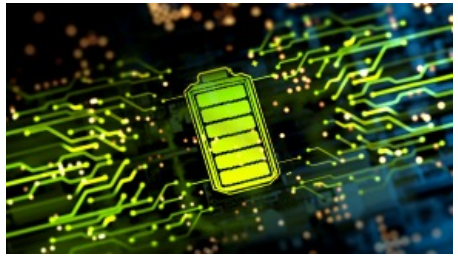
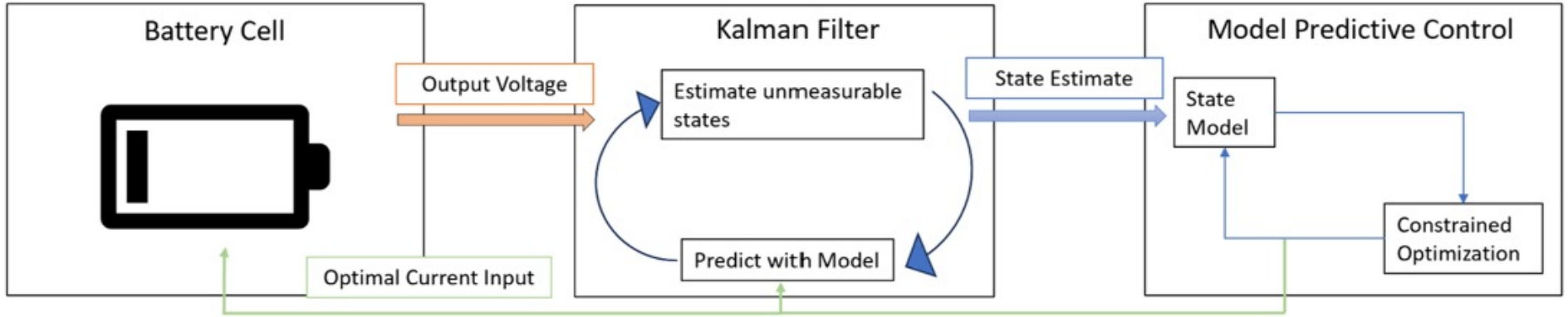
Fast-Charging

- How fast can we charge a cell while avoiding constraints and ensuring cell health?

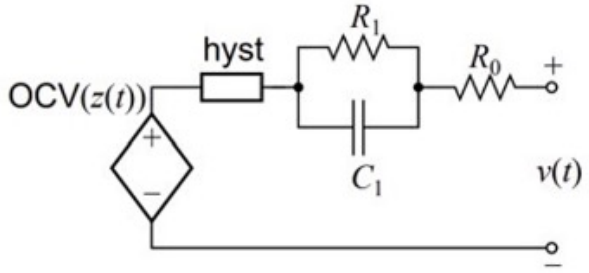


Power-Limits

- How can we efficiently estimate and utilize available power for best performance and battery life?



Equivalent-Circuit Modeling:
Empirical battery model.

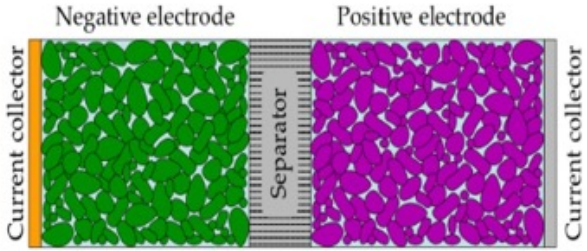


Foundational Components

Kalman Filters: Method to estimate unmeasurable quantities in a model.

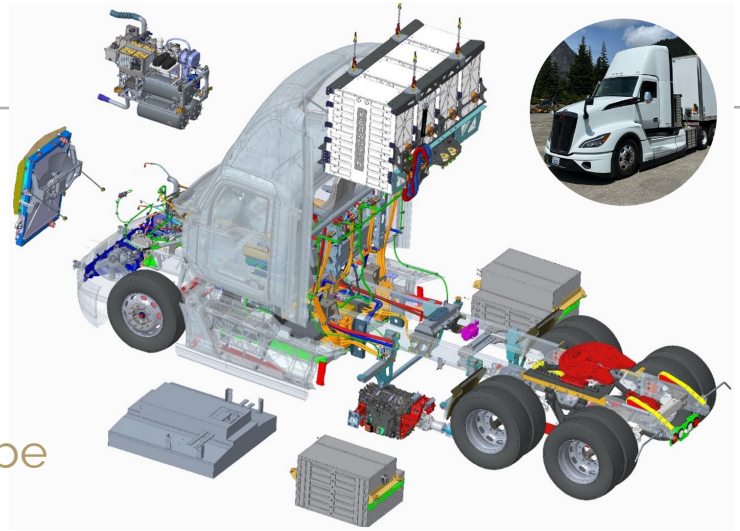
Types: SPKF EKF

Physics-Based Modeling:
First-principles based model.



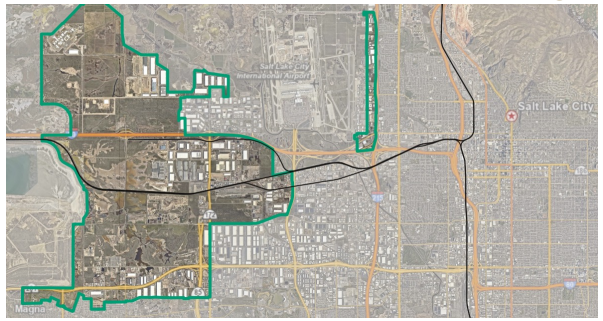
Megawatt Wireless Charging System

- Megawatt stationary inductive wireless charger for Class 8 trucks — coordinated with Kenworth.
  - completed assembly and 1800+ miles of validation testing; truck and charger will be deployed in Utah with UPS in 2024
- Demonstrated 850 kW wireless power transfer with 95% DC-DC efficiency and single pad smaller than 2 m^2
- Two UPS routes with significant elevation change and cold climates
  - SLC to Logan, UT (193 miles)
  - SLC to Orem, UT (187 miles)
- **Enabling pilot demonstrations in real-world scenarios**
- **Assisting future Utah I-15 corridor projects**

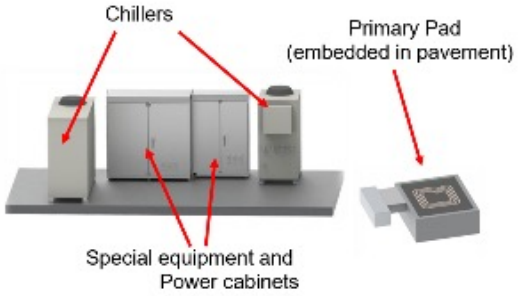


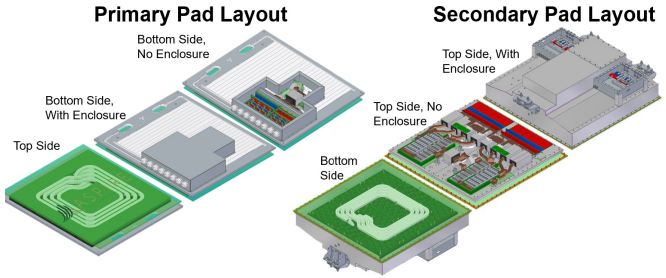
3D CAD model and photograph of the Kenworth Class 8 truck with a 1 MW wireless charger.

Class 8 truck, Falcon developed by Kenworth, will be operated by UPS.



Location of the MW wireless charging pilot.



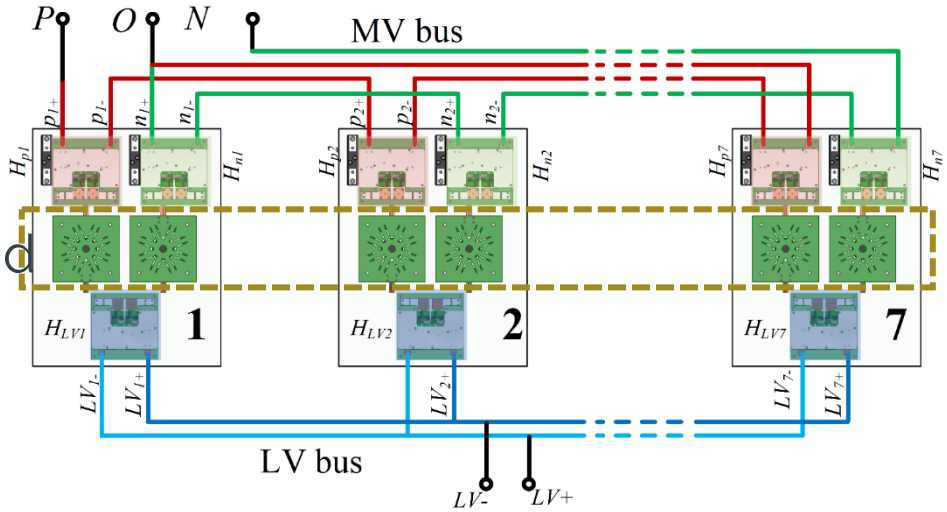


Pad layouts of the MW system.

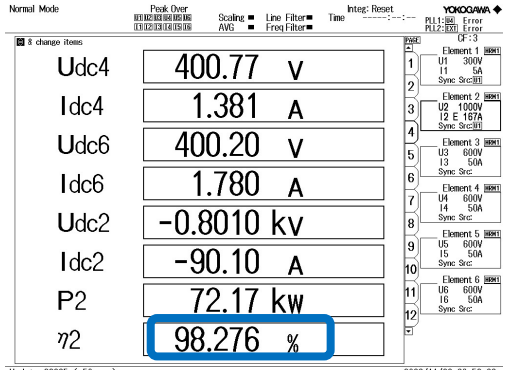
System hardware layout for the 1 MW wireless charging pilot at Utah Inland Port.

Medium Voltage Grid Interface AC-DC Converter

- **Grid connection solution for multi-megawatt and beyond**
- ASPIRE developed Unfolder based converter topology
- Novel transformer design for high-power, high-frequency, and medium voltage isolation
- Completed initial MV components testing
- Completed Unfolder and DC-DC modules standalone testing
- **Serve as main grid connection for a charging station OR a multi-MW, multi-port charger**



Assembly for the 480V pre-charge circuit and main contactor.



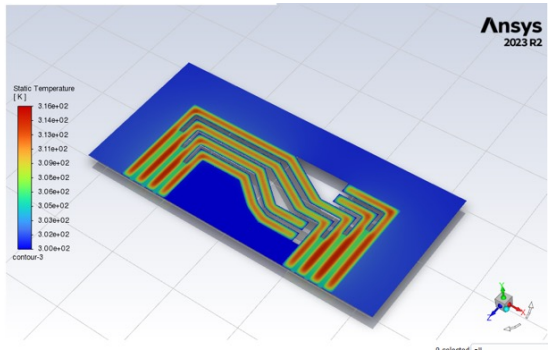
Efficiency measurement of the DC-DC module.

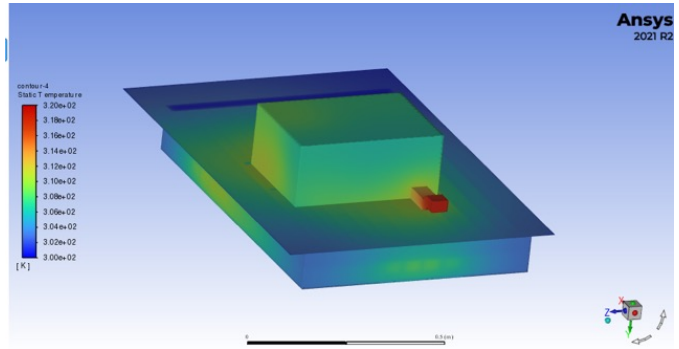
4.16 kV 3-phase AC, 560 kW modular DC fast charger.

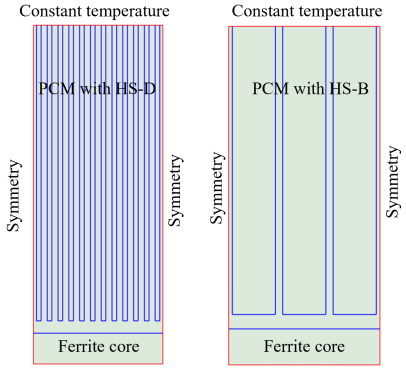
Thermal Management & Reliability of High-Power Chargers

ASPIRE

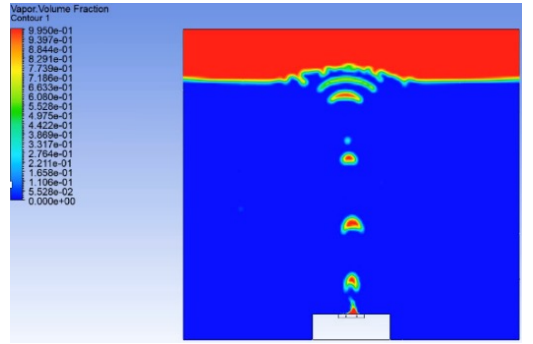
- **Address the thermal management challenge**
- **Address the charging anxiety**
- Developed thermal model for the MW wireless charging pads
- Developed a component-based numerical model for the Ferrite core with a heat sink integrated with PCM
- Conducted a user experience survey to study reliability related charging experience
- Collected aging data of total 27,598 cycles (total 2045 hours) for SiC MOSFET used in the MW charging system
- Developed a Bayesian multiple change-point modeling framework using Gamma process for SiC MOSFET RUL estimation

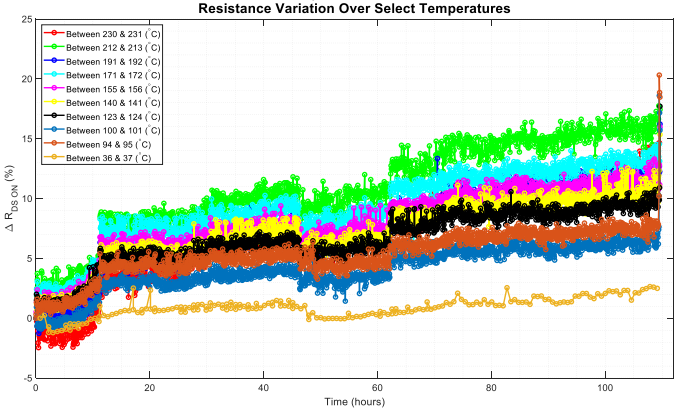


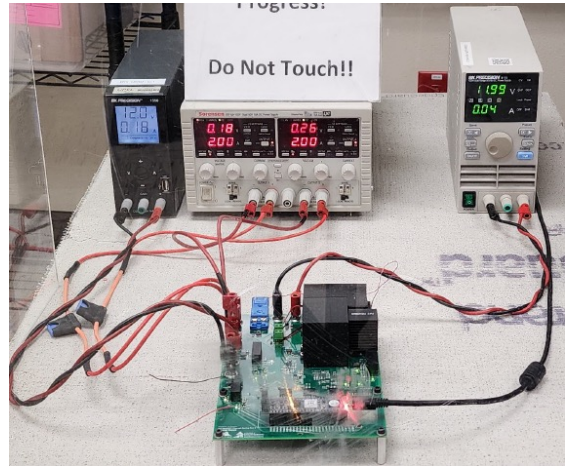




Volumetric heat generation on Ferrite core
800,000 W/m³

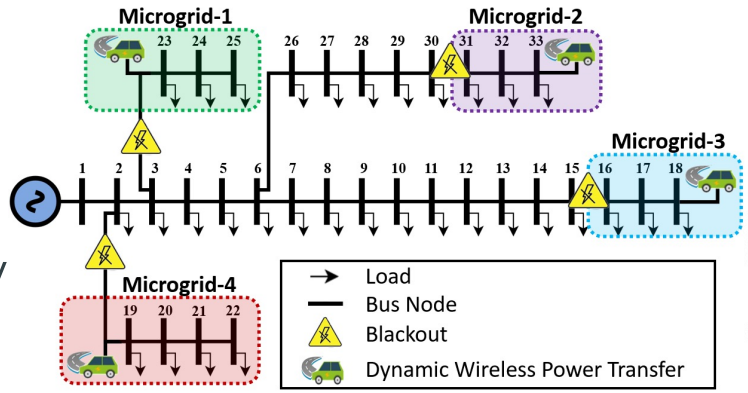


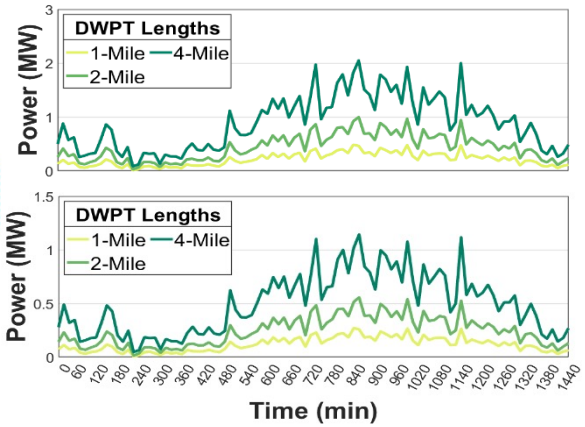


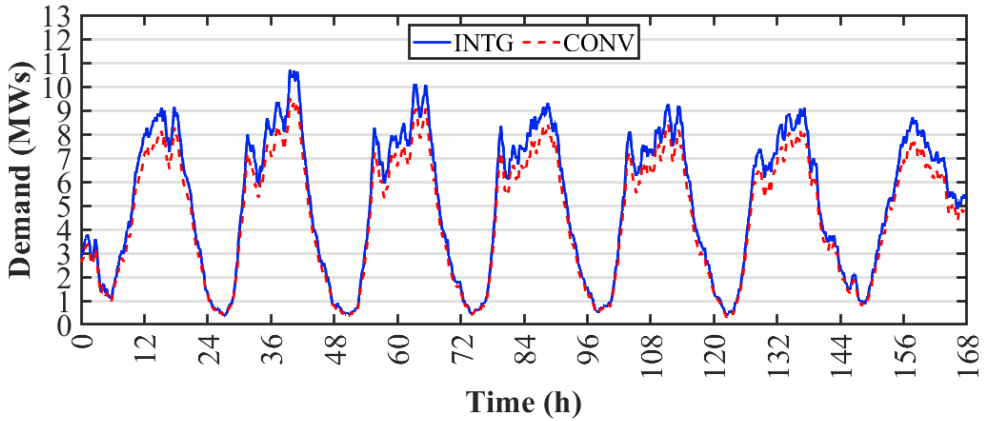


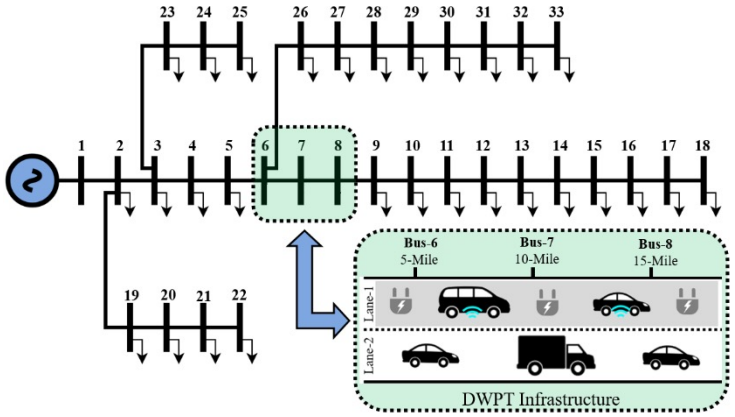
Grid Impact From Large-Scale Charging Stations

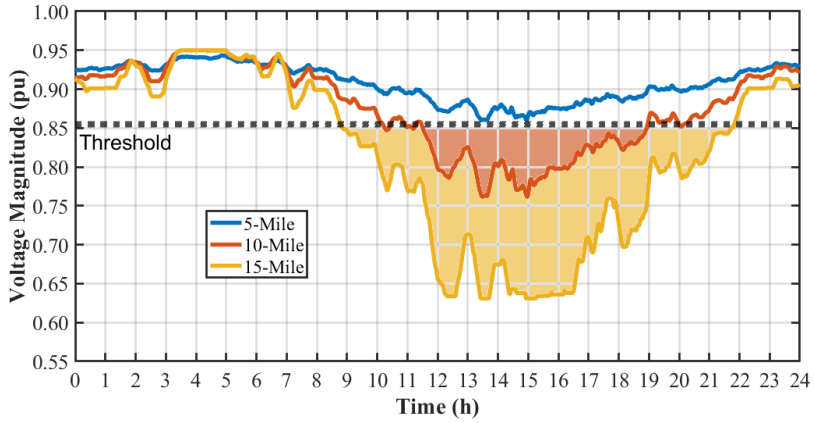
- Developed a model to study the feasibility of utilizing DWPT transportation networks in a V2G operation during unforeseen outage events
- Developed models to study the voltage stability and resiliency of distribution grid with large-scale charging loads
- Dynamic wireless power transfer roadway was used as a case study, while the developed approach can be used for other scenarios





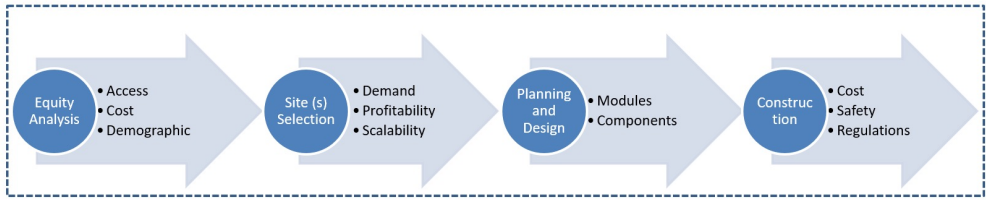


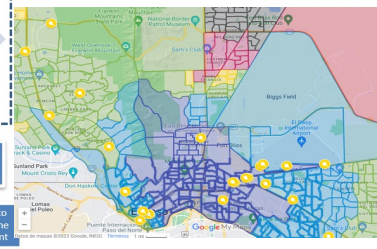


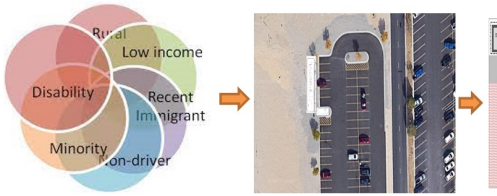


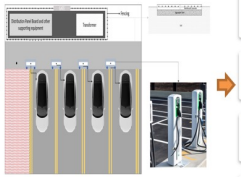
Charging Station Planning

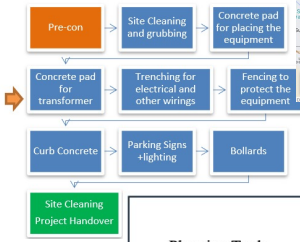
- Developing a web map and other decision tools to inform EV charging station location decisions, used to support **El Paso** governments and the utility company decide where to locate new EV charging stations obtained through a federal Charging and Fueling Infrastructure (CFI) grant
- Developed theoretical foundations for quantifying equity in EV charging infrastructure deployment, based on equity/justice theories, using the transportation concept of accessibility
- Explored and compared existing EVCI planning tools comprehensively
- Developed multiple prototypes of charging station site design, landscaping, and zoning

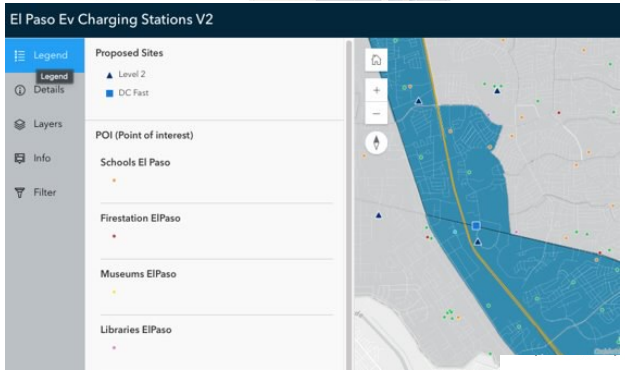


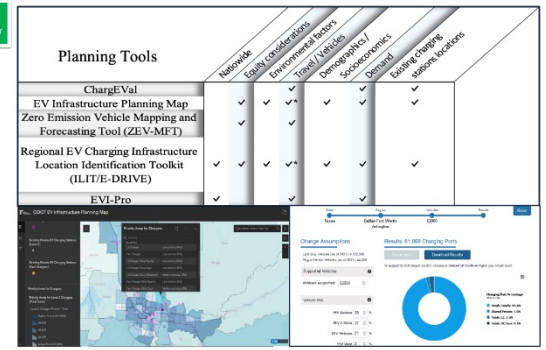


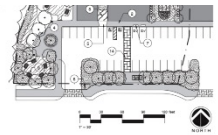


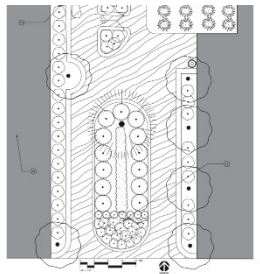


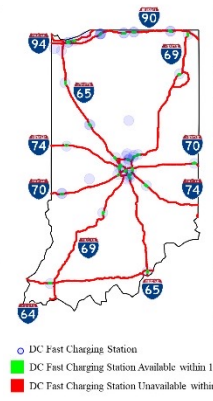


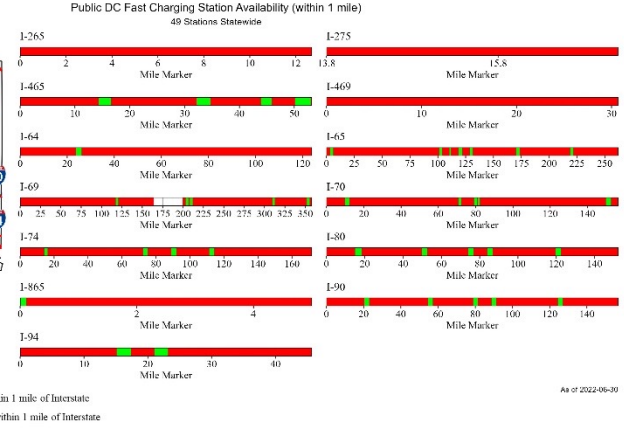






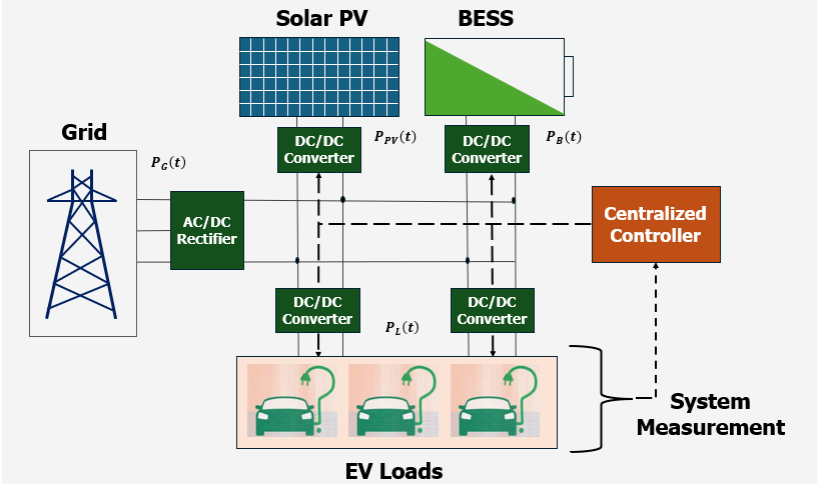


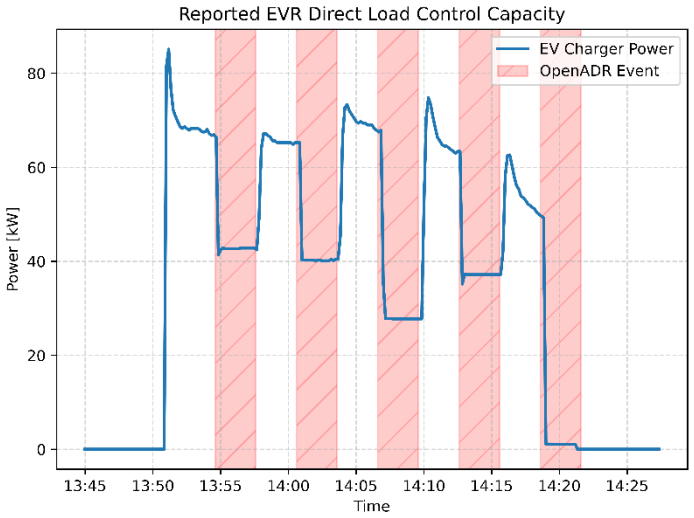


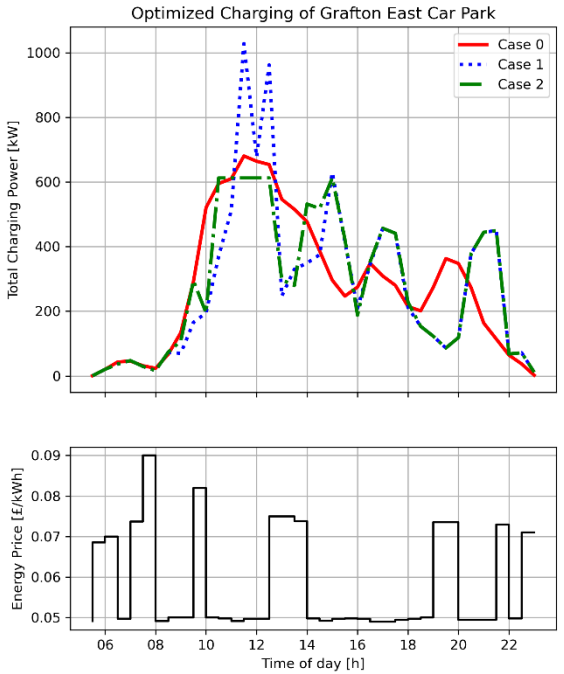


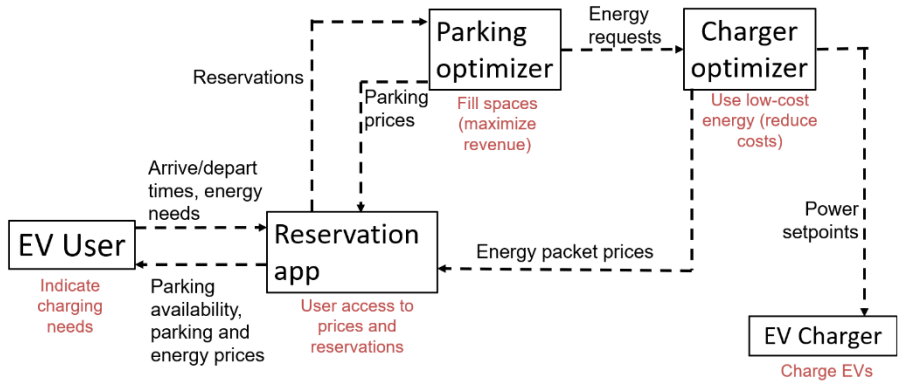
Charging Station Operation & Management

- **Reduce the charging cost through smart charging management**
- Demonstrated the control of DC fast chargers at ASPIRE hardware testbed through OpenADR for implementing smart charging management algorithms
- Developed an energy packet reservation and optimization system for EV energy cost and charging station peak demand reduction
- Studied using SARSA reinforcement learning for power scheduling and cost optimization of charging station



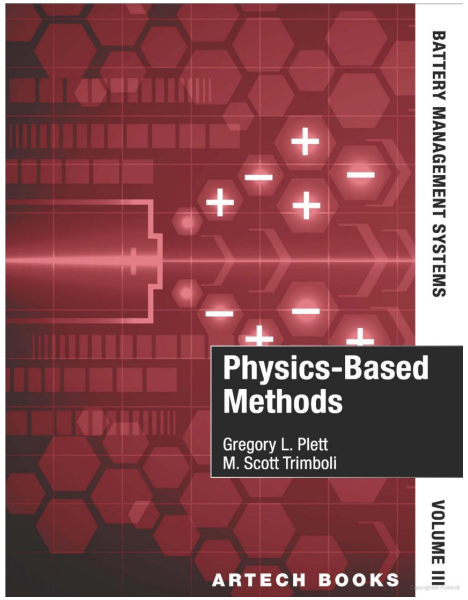


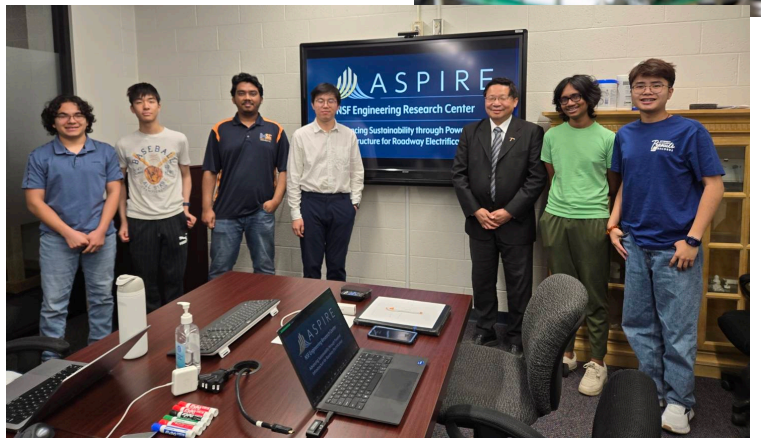




Next-Generation Engineering Workforce

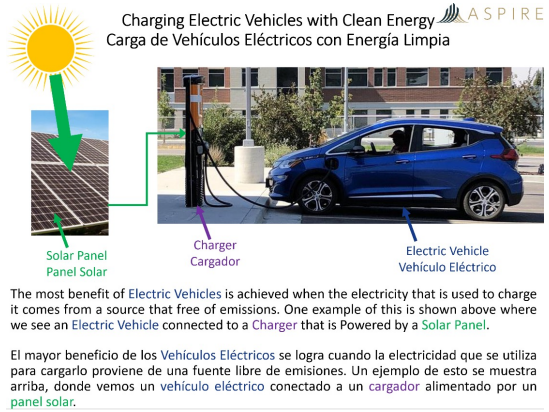
- New textbook: “Battery Management Systems: Volume III Physics-based Methods” published
- USU undergraduate student team among finalists at the 2024 International Future Energy Challenge competition (2019 4th, 2022 1st, 2023 3rd)
- In collaboration with Project 4, provided ASPIRE meet & greet presentations to high school students in Utah, Texas, and Colorado to share experiences and engage the students around the pursuit of an engineering career
- One 2024 IEEE PELS Ph.D. Thesis Talk Award (P3 Talk) Winner
- Delivered lectures as part of the ASPIRE Electrified Transportation System course offered in Spring 2024
- In collaboration with Project 4, students participated in NSF REU and internship programs

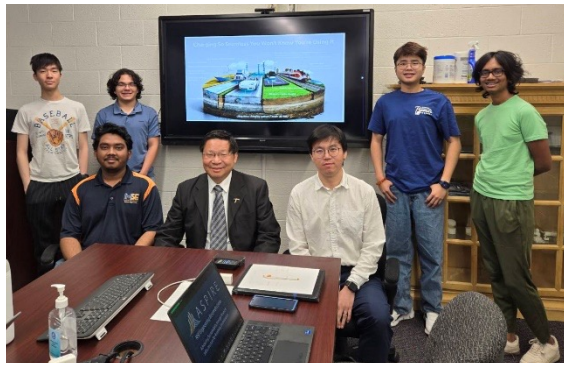


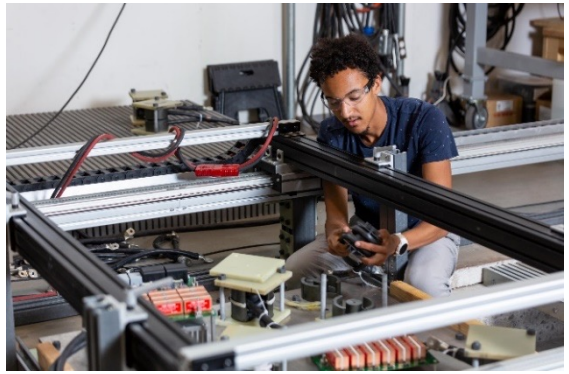


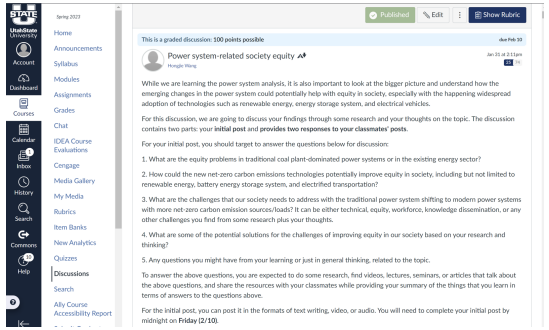
Diversity & Culture Inclusion

- Hired more than 15 graduate and undergraduate students from low-income, female, and marginalized backgrounds as research assistants working on the project
- Hosted high school students from Franklin High and Coronado High, attended the UTEP IMSE High School STEM Workshop in Machine Learning (ML)
- In collaboration with Project 4, public education materials in both English and Spanish, used for the annual ASPIRE Open House event at USU, were updated and expanded
- Introduced access-related modules in the existing engineering curriculum to engage the students in discussions on equity
- In collaboration with Project 4, participated in K-12, public, and community outreach activities









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Thank You!

Questions?

Panel Discussion

What will define charging stations of the future?

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Shubhangi Gurudiwan
Graduate Research Assistant, Power Electronics,
Utah State University

Panel Questions

ASPIRE

What are the TOP 5 barriers to the wide deployment of charging stations?

Panel Questions

ASPIRE

What tool(s) and/or knowledge do you wish to have when you work on charging station-related projects?

Panel Questions

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What are the TOP 5 considerations for the deployment of charging stations?

Panel Questions

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What are the skills/capabilities you want to see when you hire someone working in a charging station/system-related position?

Panel Questions

ASPIRE

How can ASPIRE's CSoF project help address the discussed barriers, challenges, and needs?