



ASPIRE

# Charging Stations of the Future

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What will define charging stations of the future?



**Hongjie Wang**

*Project 1: CSoF Lead*







































*Assistant Professor, USU*

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# Project 2: CSoF Faculty



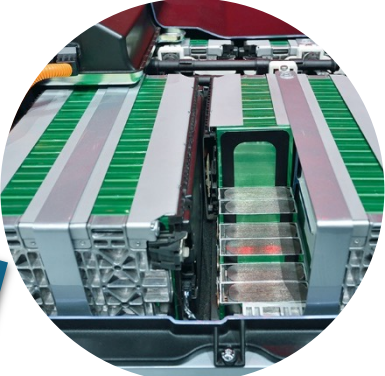
- Electrical Engineering
- Mechanical Engineering
- Industrial & System Engineering
- Civil Engineering
- Business
- Economics
- Marketing
- Social Science

												
<a href="#"><u>Brandon Allen</u></a> DCI Co-director Purdue	<a href="#"><u>Adeeba A. Raheem</u></a> Civil Engineering UTEP	<a href="#"><u>Sharad Jones</u></a> Data analytics USU	<a href="#"><u>Rose Hu</u></a> Electrical Engineering USU	<a href="#"><u>Dragan Maksimovic</u></a> EWD Co-director UC Boulder	<a href="#"><u>Fawn Groves</u></a> Community Engagement USU	<a href="#"><u>Hongjie Wang</u></a> Project Co-lead USU	<a href="#"><u>Emma Mecham</u></a> Teacher Education USU	<a href="#"><u>Scott Trimboli</u></a> Project Co-lead UCCS	<a href="#"><u>Honglun Xu</u></a> Industrial Engineering UTEP	<a href="#"><u>Simon Bickerton</u></a> Mechanical Engineering UoA	<a href="#"><u>Minh Kieu</u></a> Civil Engineering UoA	
												
<a href="#"><u>Janette Goodridge</u></a> Economics and Finance USU	<a href="#"><u>Khurram Afridi</u></a> Electrical Engineering Cornell	<a href="#"><u>Andrea Raith</u></a> Engineering Science UoA	<a href="#"><u>Grant Covic</u></a> Director of UoA UoA	<a href="#"><u>Patrick Singleton</u></a> Project 3 Co- lead USU	<a href="#"><u>Gregory Plett</u></a> Electrical Engineering UCCS	<a href="#"><u>Ole Sleipness</u></a> Environmental Planning USU	<a href="#"><u>Bill Tseng</u></a> Industrial Engineering UTEP	<a href="#"><u>Rosalee Clawson</u></a> DCI director Purdue	<a href="#"><u>Regan Zane</u></a> Electrical Engineering USU	<a href="#"><u>Sharmin Abdullah</u></a> Data Sciences GMU	<a href="#"><u>Michael Pokojov</u></a> Mathematical Sciences UTEP	<a href="#"><u>Hailei Wang</u></a> Mechanical Engineering UoA
												
<a href="#"><u>Ivonne Santiago</u></a> Civil Engineering UTEP	<a href="#"><u>Ziqi Song</u></a> Transportation Co-lead USU	<a href="#"><u>Darcy Bullock</u></a> Civil Engineering Purdue	<a href="#"><u>Paras Mandal</u></a> Electrical Engineering UTEP	<a href="#"><u>Jennifer Ramos-Chavez</u></a> Civil Engineering UTEP	<a href="#"><u>Duleepa J Thrimawithana</u></a> Electrical Engineering UoA	<a href="#"><u>Wade Goodridge</u></a> Engineering Education USU	<a href="#"><u>Seho Kim</u></a> Electrical Engineering UoA	<a href="#"><u>Rajnish Sharma</u></a> Mechanical Engineering UoA	<a href="#"><u>Tumanako Fa'au</u></a> Civil Engineering UoA	<a href="#"><u>Nicholas Roberts</u></a> Mechanical Engineering USU	<a href="#"><u>Jairaj Desai</u></a> Civil Engineering Purdue	<a href="#"><u>Jackman Lir</u></a> Electrical Engineering UoA



New Team Members

# Charging Stations of the Future



**Battery  
Modeling  
& Control**



**High  
Power  
Charging**



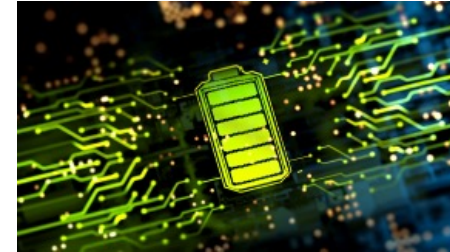
**Charging Station  
Location,  
Economics, &  
Management**

# Battery Modeling & Control



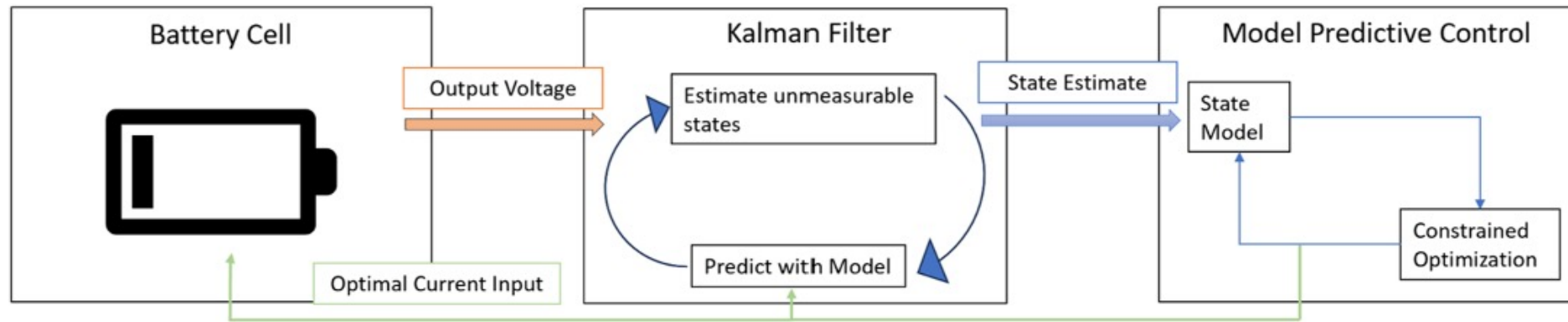
## Fast-Charging

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



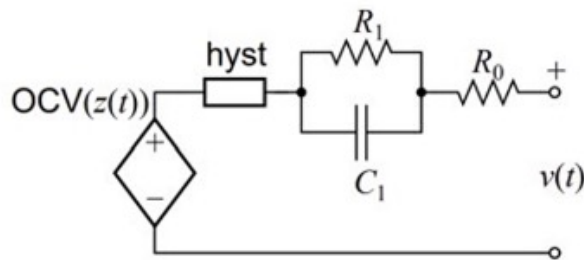
## Power-Limits

- 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.

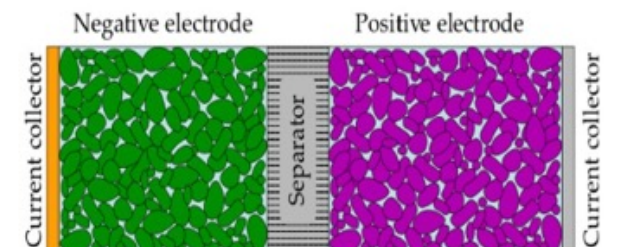
Types:

SPKF

EKF

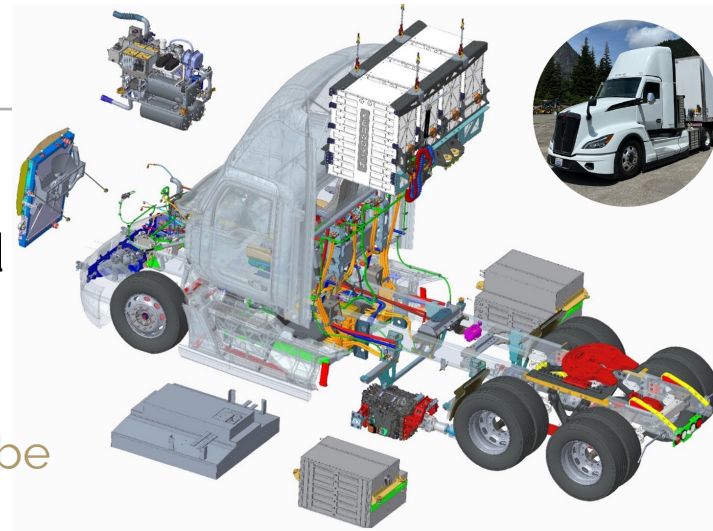
## Physics-Based Modeling:

First-principles based model.



# Megawatt Wireless Charging System

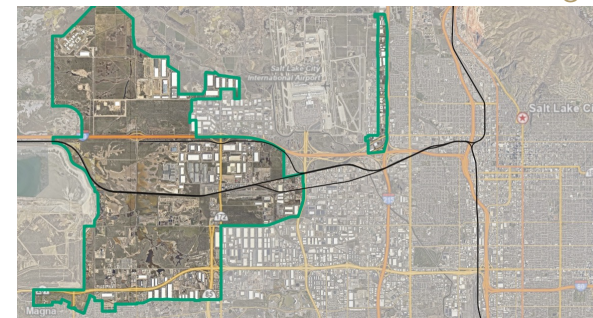
- Megawatt stationary inductive wireless charger for Class 8 trucks — coordinated with Kenworth.
  - completed assembly and 1800+ miles of validation testing; truck and charger will be deployed in Utah with UPS in 2024
- Demonstrated 850 kW wireless power transfer with 95% DC-DC efficiency and single pad smaller than 2 m<sup>2</sup>
- 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



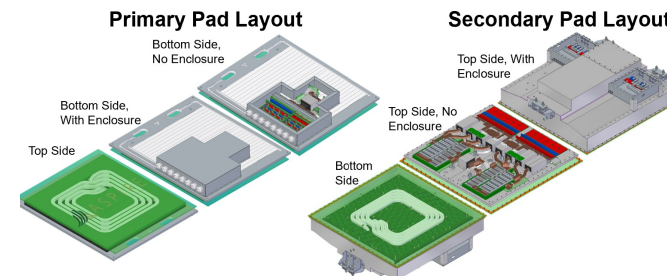
3D CAD model and photograph of the Kenworth Class 8 truck with a 1 MW wireless charger.



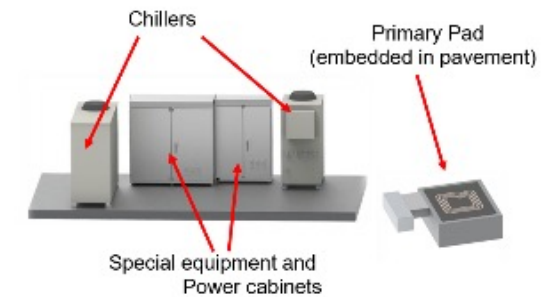
Class 8 truck, Falcon developed by Kenworth, will be operated by UPS.



Location of the MW wireless charging pilot.



Pad layouts of the MW system.

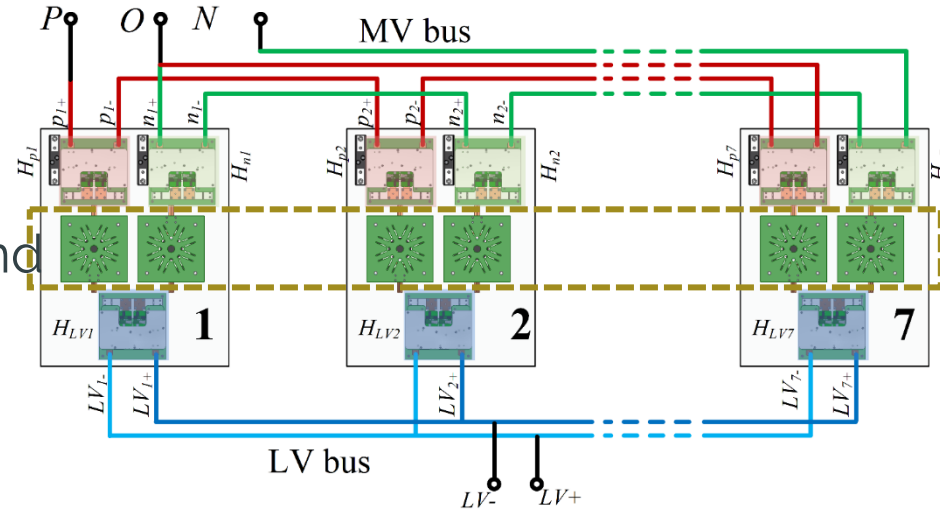


System hardware layout for the 1 MW wireless charging pilot at Utah Inland Port.

# 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.

Parameter	Value	Unit
Udc4	400.77	v
I <sub>dc4</sub>	1.381	A
Udc6	400.20	v
I <sub>dc6</sub>	1.780	A
Udc2	-0.8010	kV
I <sub>dc2</sub>	-90.10	A
P2	72.17	kW
$\eta_2$	98.276	%

Efficiency measurement of the DC-DC module.

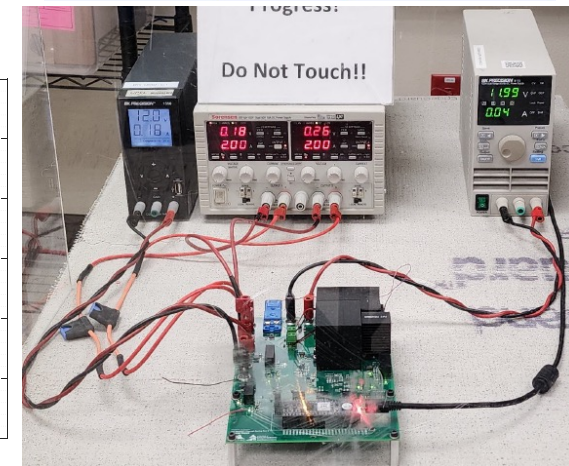
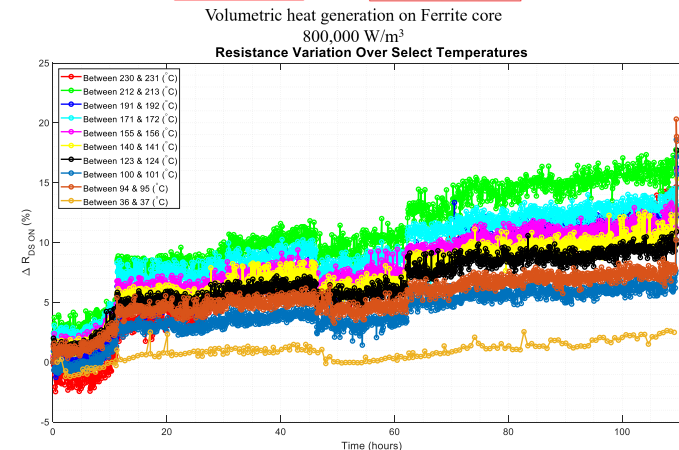
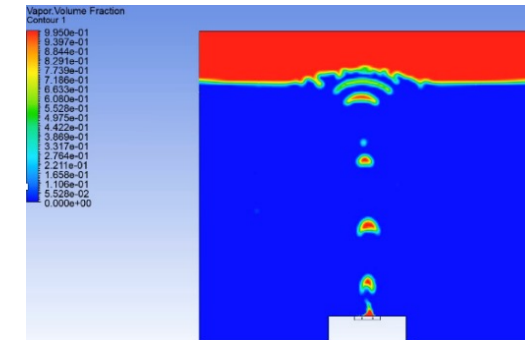
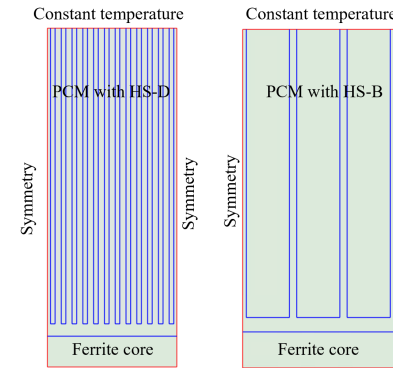
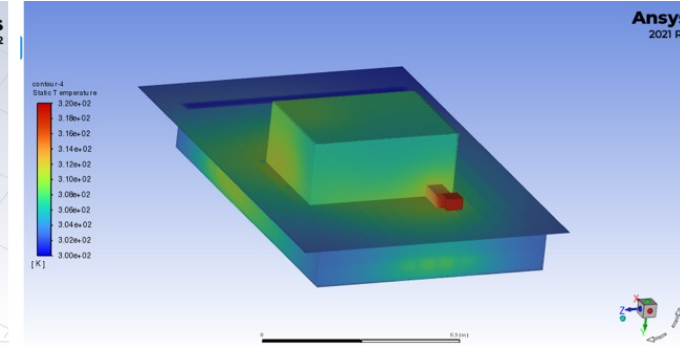
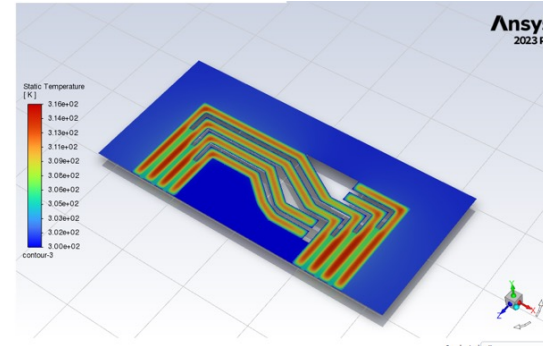


4.16 kV 3-phase AC, 560 kW modular DC fast charger.

# Thermal Management & Reliability of High-Power Chargers

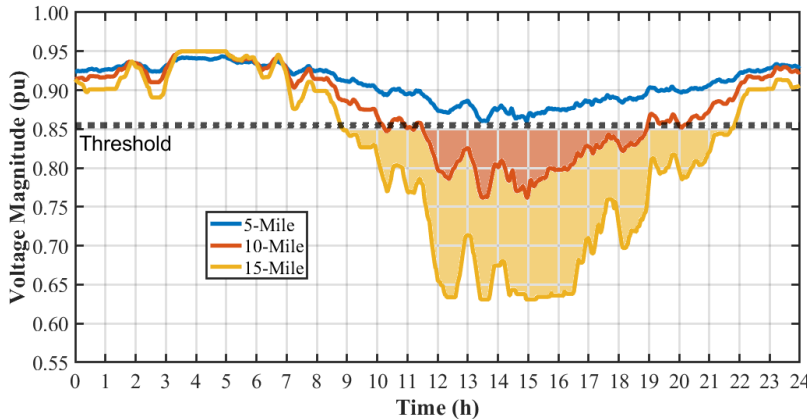
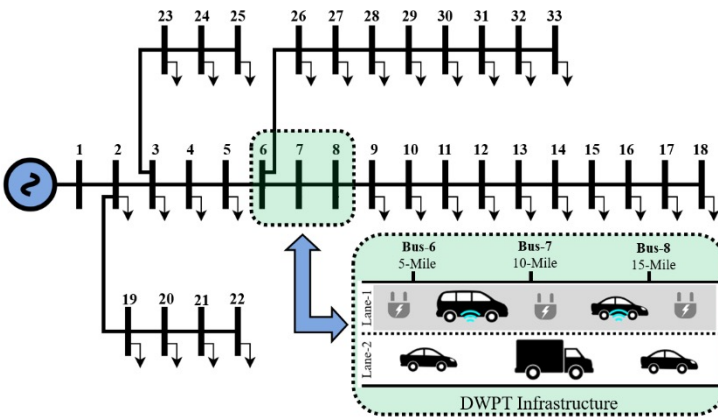
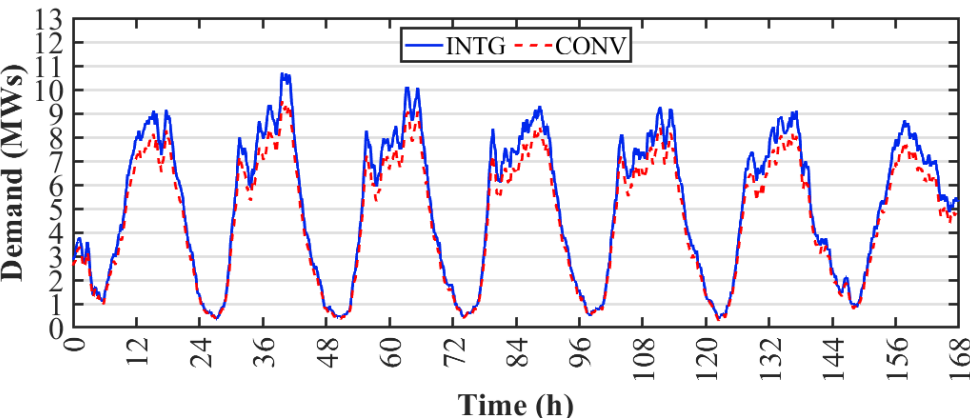
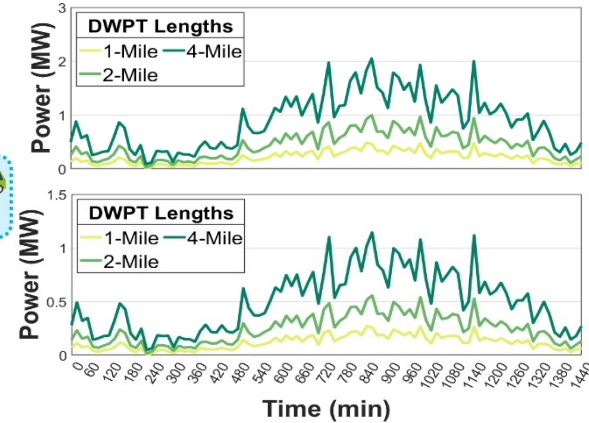
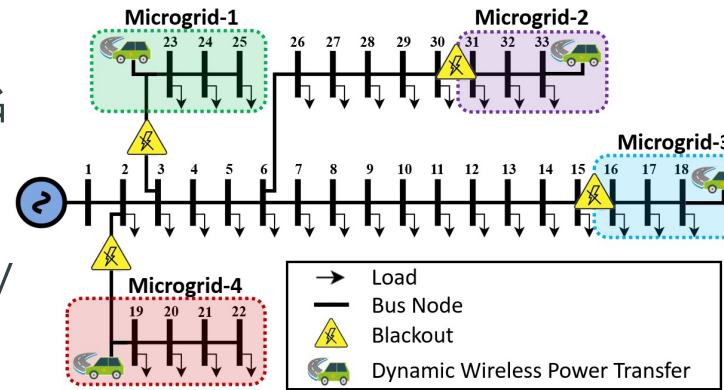


- Address the thermal management challenge
- Address the charging anxiety
- Developed thermal model for the MW wireless charging pads
- Developed a component-based numerical model for the Ferrite core with a heat sink integrated with PCM
- Conducted a user experience survey to study reliability related 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



# 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

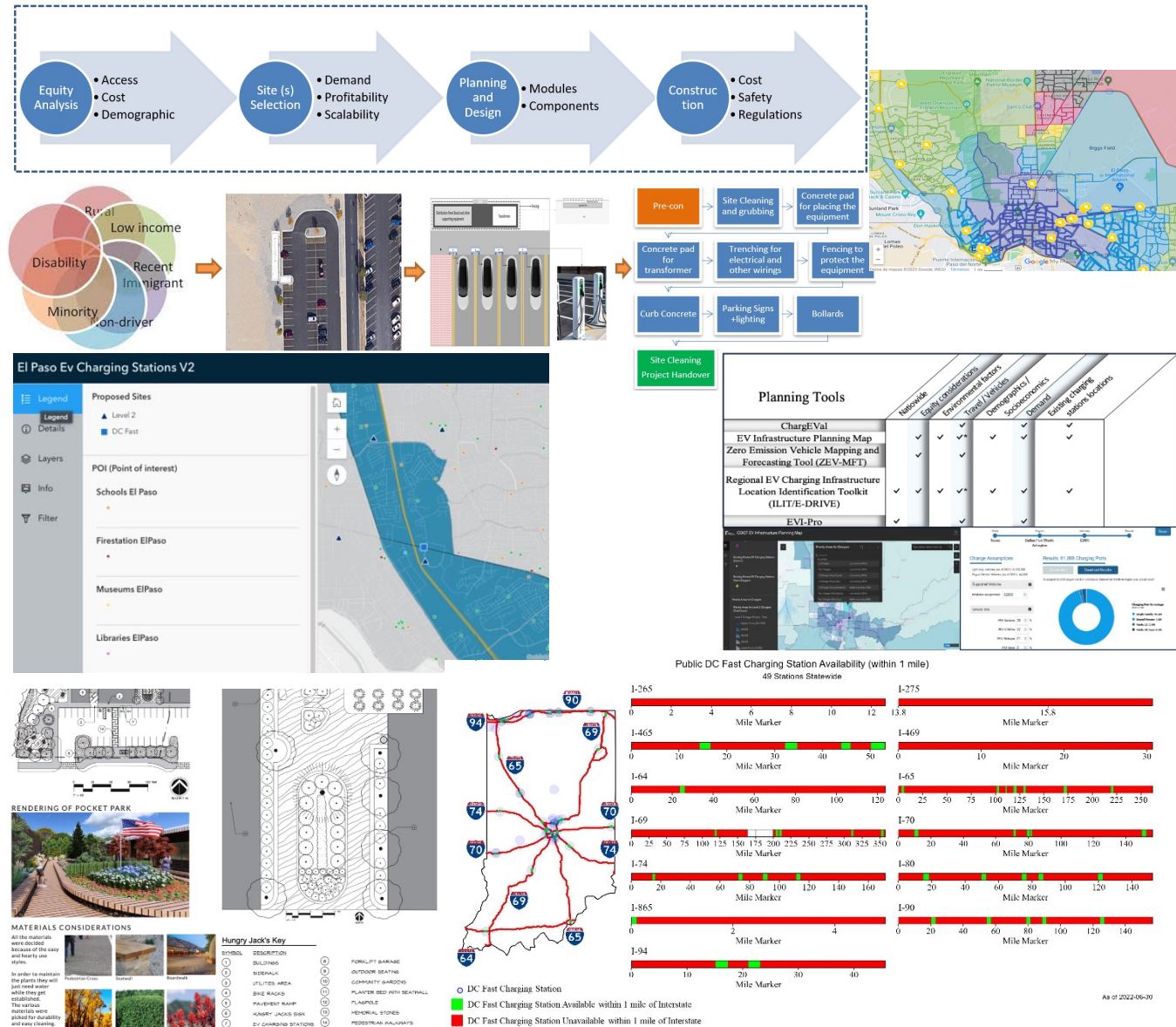




# Charging Station Planning



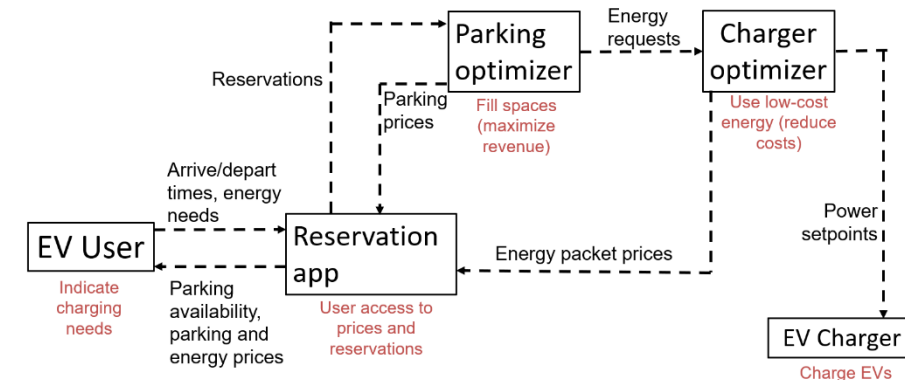
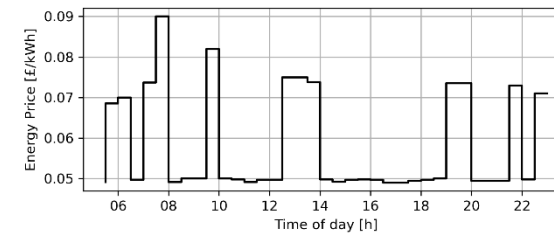
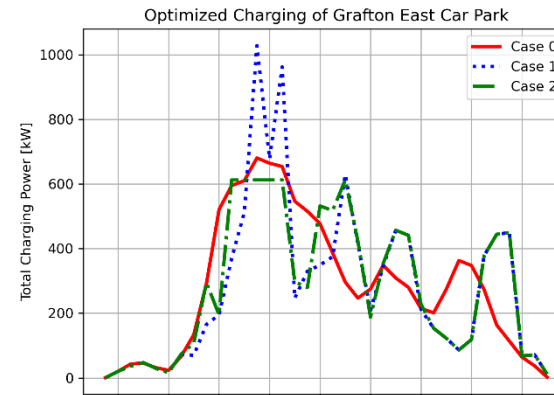
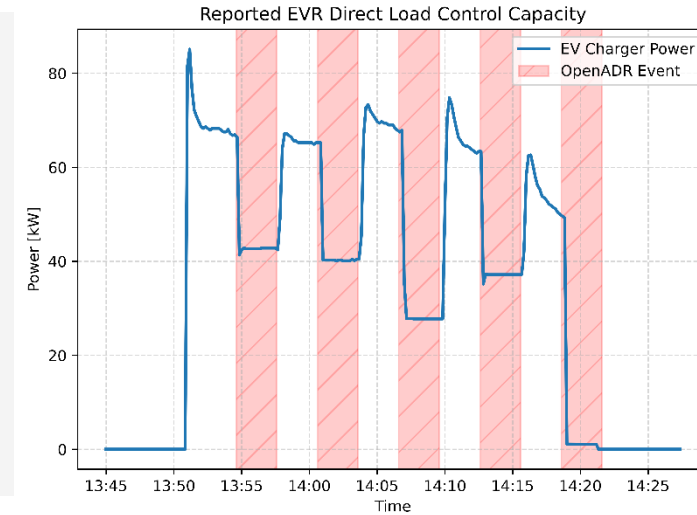
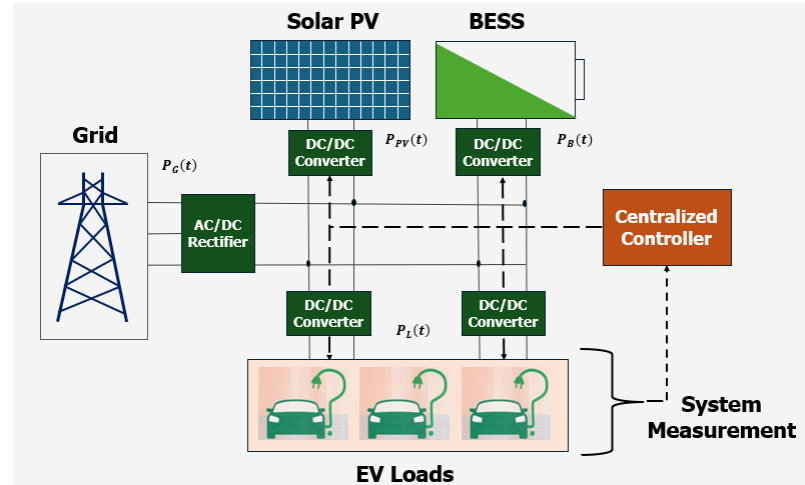
- Developing a web map and other decision tools to inform EV charging station location decisions, used to support **El Paso** governments and the utility company decide where to locate new EV charging stations obtained through a federal Charging and Fueling Infrastructure (CFI) grant
- Developed theoretical 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



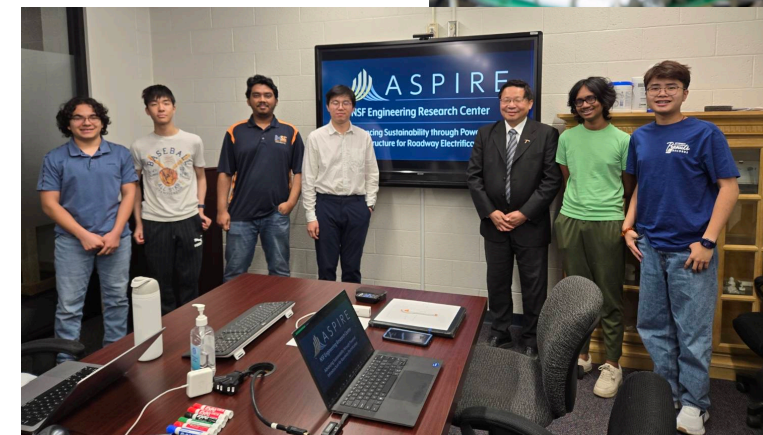
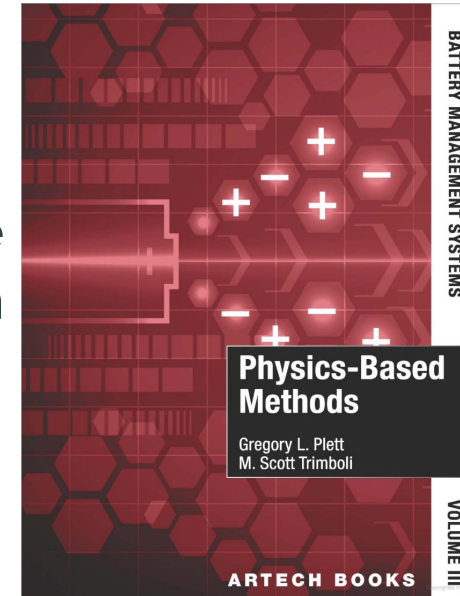
- Reduce the charging cost through smart charging management
- Demonstrated the control of DC fast chargers at ASPIRE hardware testbed through OpenADR for implementing smart charging management algorithms
- Developed an energy packet reservation and optimization system for EV energy cost and charging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



# Next-Generation Engineering Workforce



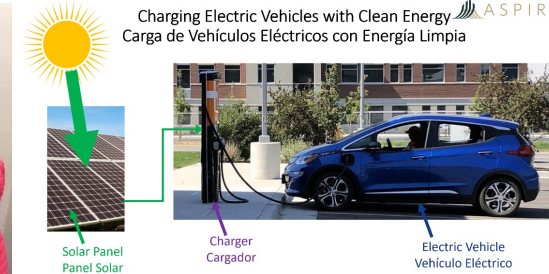
- New textbook: “Battery Management Systems: Volume III Physics-based Methods” published
- USU undergraduate student team among finalists at the 2024 International Future Energy Challenge competition (2019 4<sup>th</sup>, 2022 1<sup>st</sup>, 2023 3<sup>rd</sup>)
- In collaboration with Project 4, provided 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

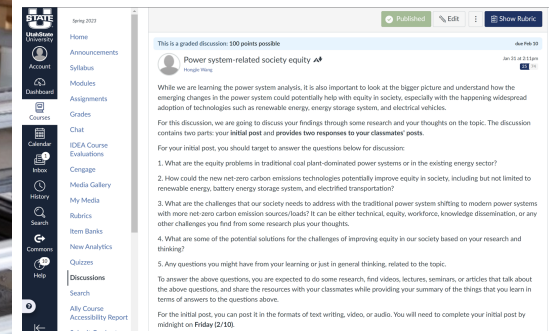
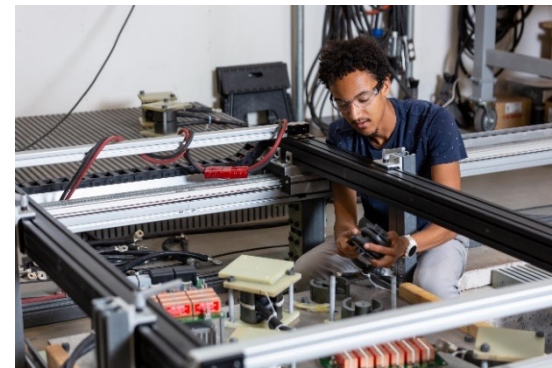
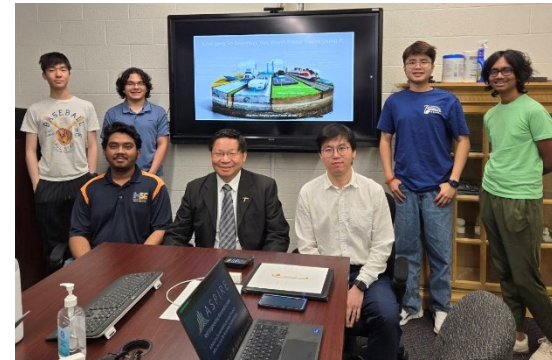


- Hired more than 15 graduate and undergraduate students from low-income, female, and marginalized backgrounds as research assistants working on the project
- Hosted high school students from Franklin High and Coronado High, attended the UTEP IMSE High School STEM Workshop in Machine Learning (ML)
- 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



The most benefit of Electric Vehicles is achieved when the electricity that is used to charge it comes from a source that is free of emissions. One example of this is shown above where we see an Electric Vehicle connected to a Charger that is Powered by a Solar Panel.

El mayor beneficio de los Vehículos Eléctricos se logra cuando la electricidad que se utiliza para cargarlo proviene de una fuente libre de emisiones. Un ejemplo de esto se muestra arriba, donde vemos un vehículo eléctrico conectado a un cargador alimentado por un panel solar.





**Hongjie Wang**

*Project 1: CSoF Lead,  
Assistant Professor, USU*

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# Thank You!

Questions?

# Panel Discussion



What will define charging stations of the future?



**MODERATOR:**  
**Tenzin Lhaden**  
*Graduate Research Assistant, Industrial Engineering*  
University of Texas at El Paso



**John Kresse**  
*Director, Advanced Electrification Technologies*  
Cummins



**Hongjie Wang**  
*Project 2: CSoF Lead,*  
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**Scott Trimboli**  
*Project 2: CSoF Lead,*  
University of Colorado, Colorado Springs



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

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

# Panel Questions

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**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

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