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High-Power Electric Vehicle Charging Hub Integration Platform (eCHIP)

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Outline

Project Overview

DC Charging Hub Overview

Site Energy Management System (SEMS) Platform Development

DC Hub Hardware Development and Results

Conclusion and Next Steps

High-Power Electric Vehicle Charging Hub Integration Platform (eCHIP)

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Objective: Develop plug-and-play solution allowing charging site to organically grow with additional chargers and DERs through predefined compatibility with standards that will ensure interoperability

Outcomes:

– Determine interoperable and scalable hardware, communication, and control architectures for high-power charging facilities
– Broadly identify limitations and gaps in DC distribution and protection systems that allow for modular HPC systems
– Develop and demonstrate solutions for efficient, low-cost, and high-power-density DC-DC for kW- and MW-scale charging

- John Kisacikoglu (PI)
- Yukihiro Hatagishi
- Derek Jackson
- Namrata Kogalur
- Vaibhav Pawaskar
- Alastair Thurlbeck
- Emin Ucer
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NREL

- Akram Ali
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- Saransh Jain
- Bryan Nystrom

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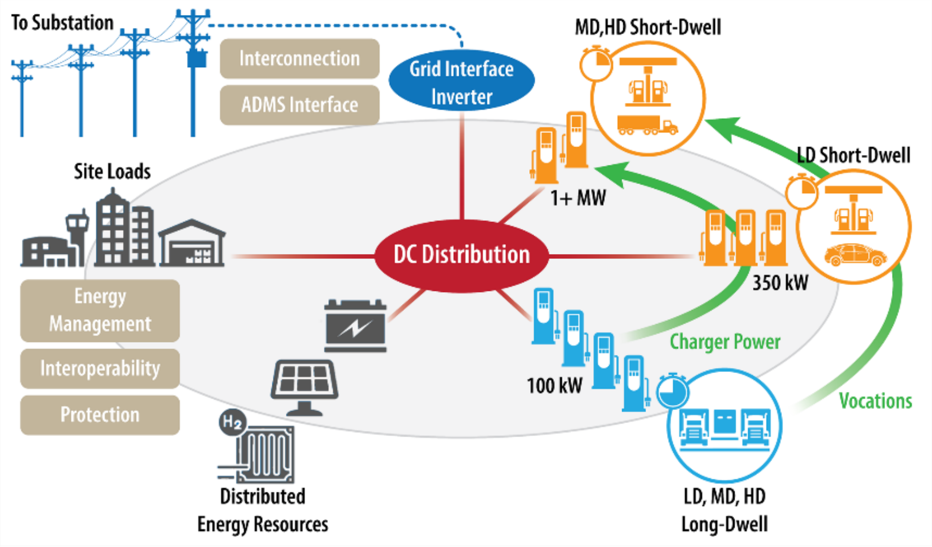
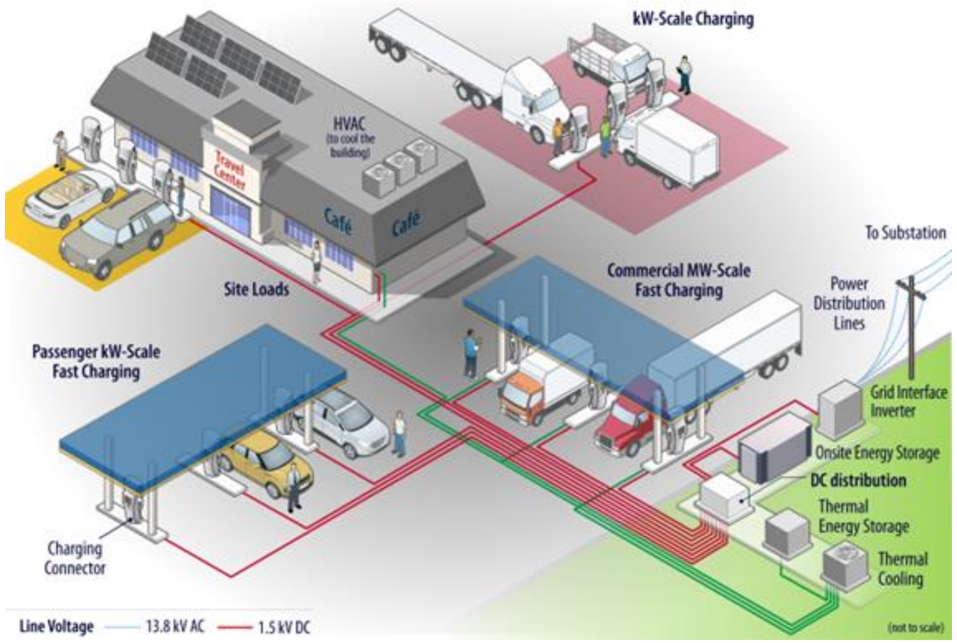
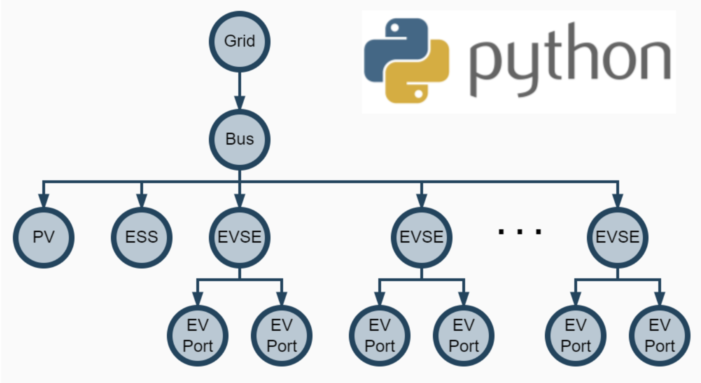


Hub Operation Analysis using EVI-EnSitePy

EVI-EnSitePy developed under eCHIP uncovers advantages of DC hub operation:

- Different hub configurations (AC or DC)
- Different distribution voltage and site/port power levels
- Cost analysis based on capital and operational expenses
- Grid peak-demand requirements
- Deep visibility on station operation
  - Charging time
  - Queuing time
  - Utilization
- Site control system implementation
- Utilization of custom charging profiles





Charging Hub with On-Site ESS and Solar PV

EVI-EnSite
https://www.nrel.gov/transportation/evi-ensite.html

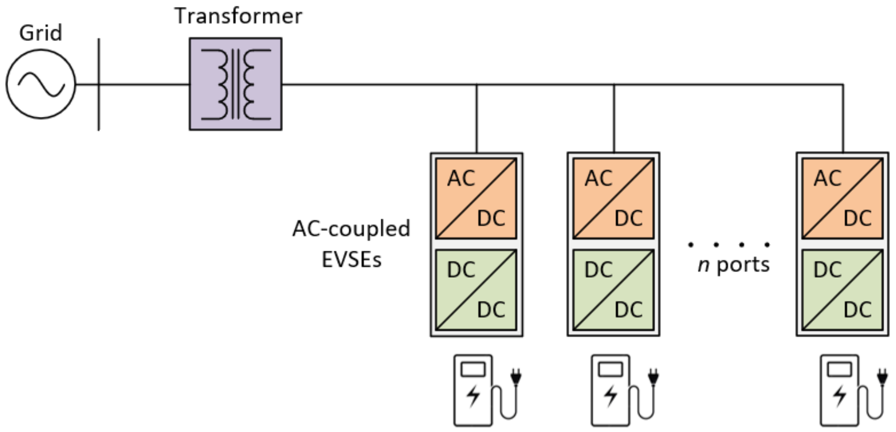
[1] D. Jackson, E. Ucer, M. J. Kisacikoglu, and A. Thurlbeck “A Comparison of AC and DC Distribution Architectures for EV High Power Charging Facilities,” ECCE, Oct. 2024, to be presented.

Overview of DC Hub Approach

Parameter	AC Hub	DC Hub
Number of AC/DC converter modules	2X	X
Power distribution cable mass	2.5X	X
Higher efficiency operation	1.08MWh-2MWh of daily energy loss	1.01MWh-1.8 MWh of daily energy loss

*For a station with 20 ports and 300 kW port capacity.

DC Hub over AC hub: ~70-200kWh of daily energy savings



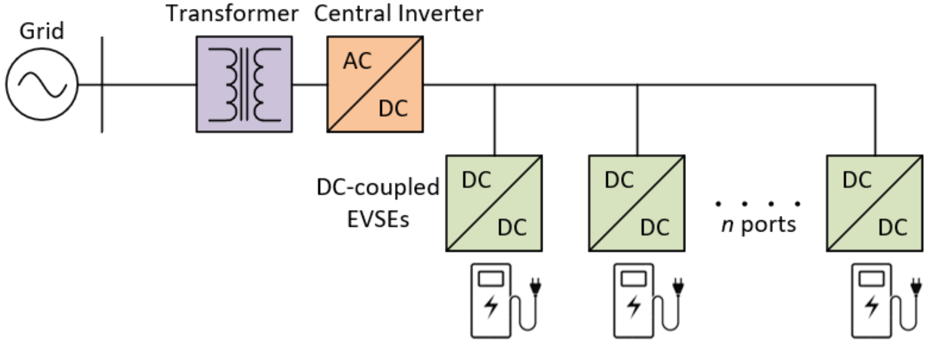
AC-Hub (AC-coupled)

Advantages continued:

- Simplified controls (no AC sync., no Q-control)
- When PV and ESS integrates, above advantages will increase

Issues with DC Hub:

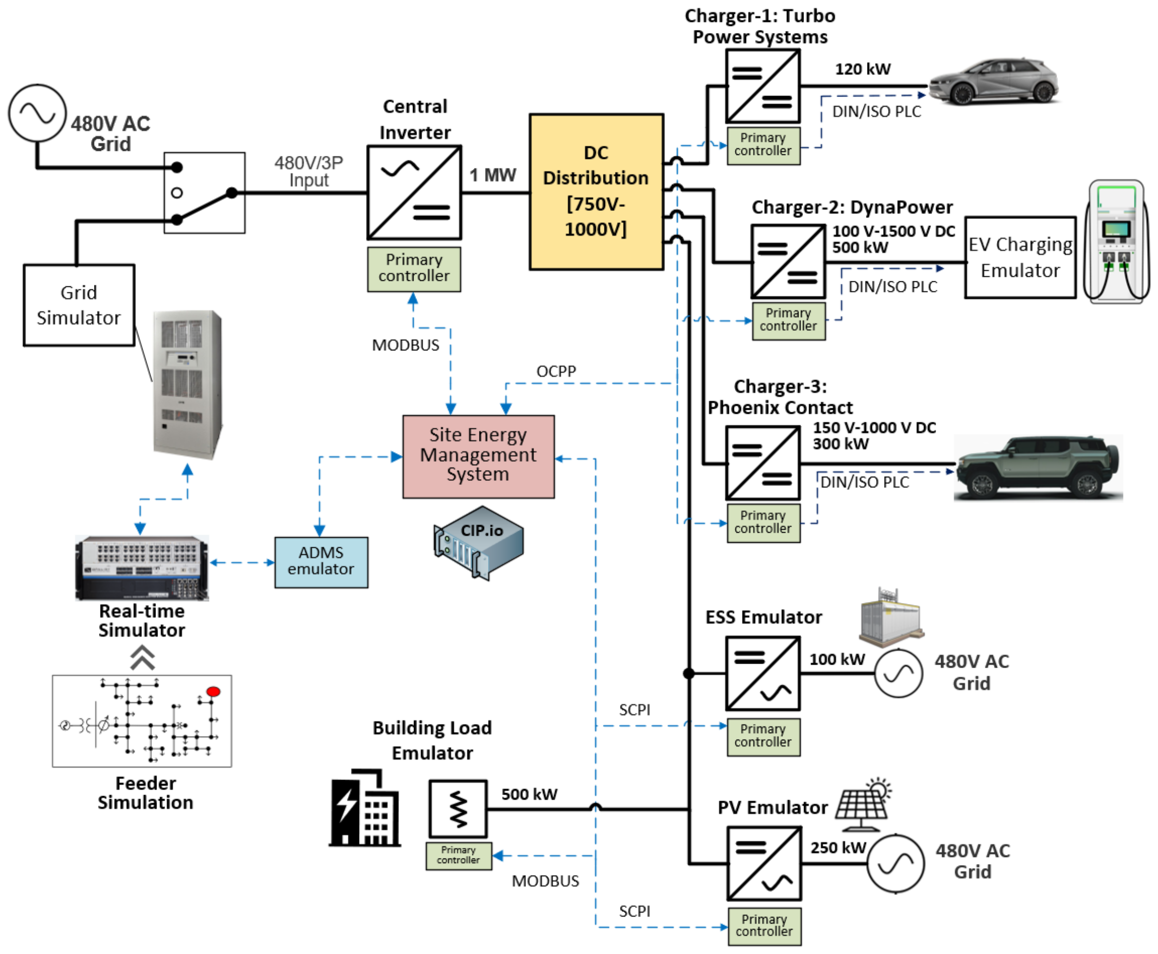
- More complex protection
- Product immaturity
- Lack of standardization for DC



DC-Hub (DC-coupled)

[1] D. Jackson, E. Ucer, M. J. Kisacikoglu, and A. Thurlbeck "A Comparison of AC and DC Distribution Architectures for EV High Power Charging Facilities," ECCE, Oct. 2024, to be presented.

DC Charging Hub Overview



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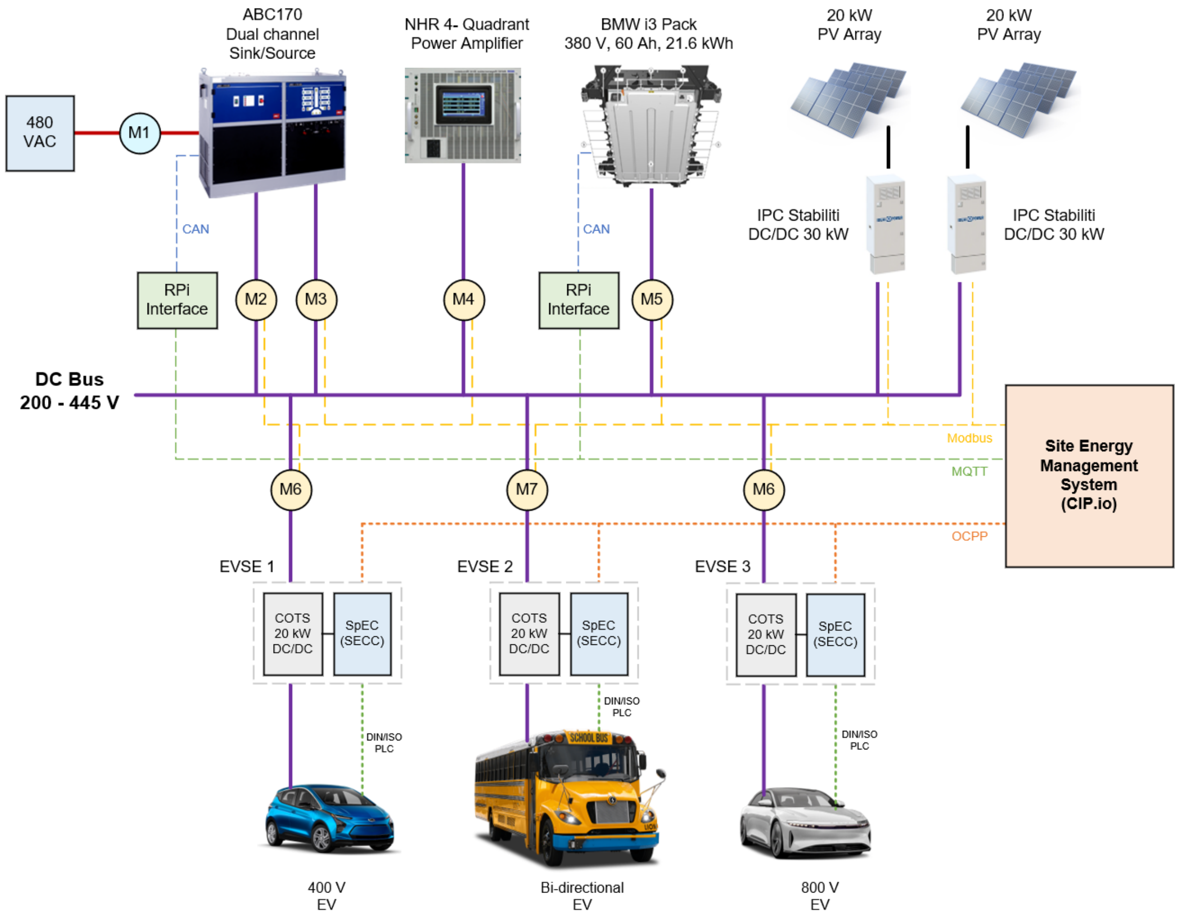

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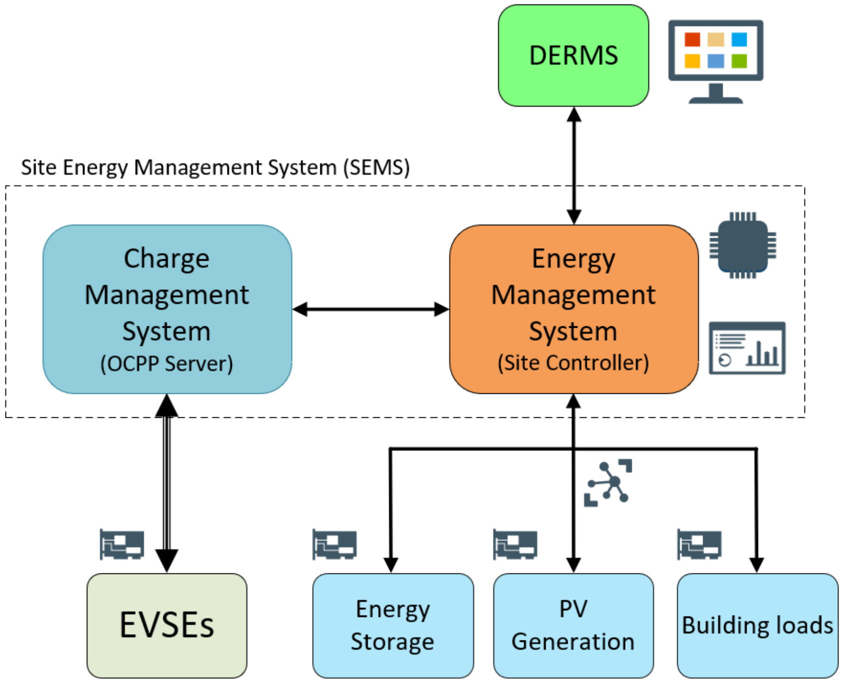
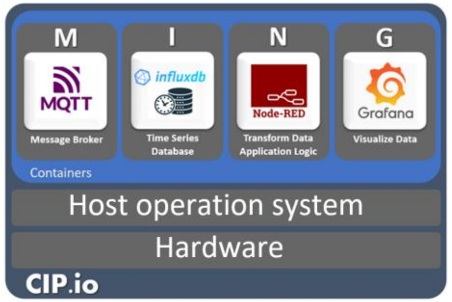
Site Energy Management System (SEMS) Platform

SEMS platform is developed by Argonne and NREL

- Real-time monitoring and control of DC hub
- OCPP 1.6J and 2.0.1 for EV charging
- MQTT for non-standardized DC hub integration monitoring and control
- Controllers will handle communication for DC chargers and EV
  - SpEC module, Vector, Pionix, Raspberry Pi, etc.
- **Custom site-control applications are created in Node-RED, Python and C/C++**

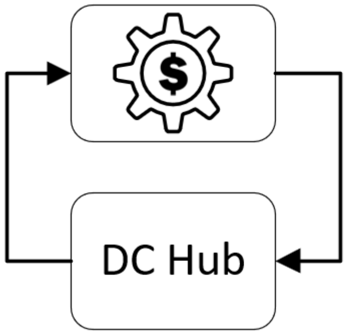




https://github.com/Argonne-National-Laboratory/CIP.io

SEMS Site Controller Approaches

Optimized



- Optimized for long-term performance
- Customizable to support complex objectives
- Centralized and slower operation
- Real-time connectivity requirement
- Requires forecasting

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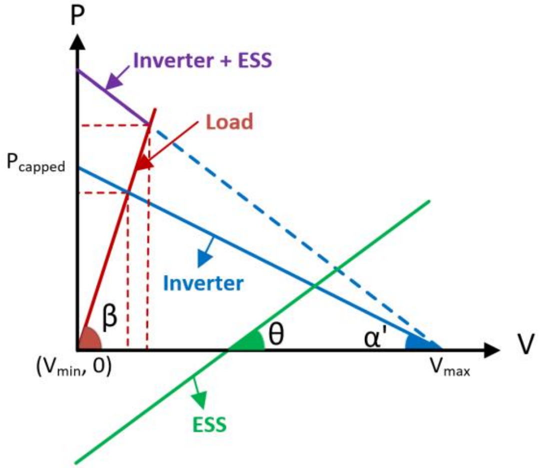
Droop-based



- Decentralized and faster operation
- Minimal communication requirement
- Sub-optimal performance
- Limited scope for defining operational objectives

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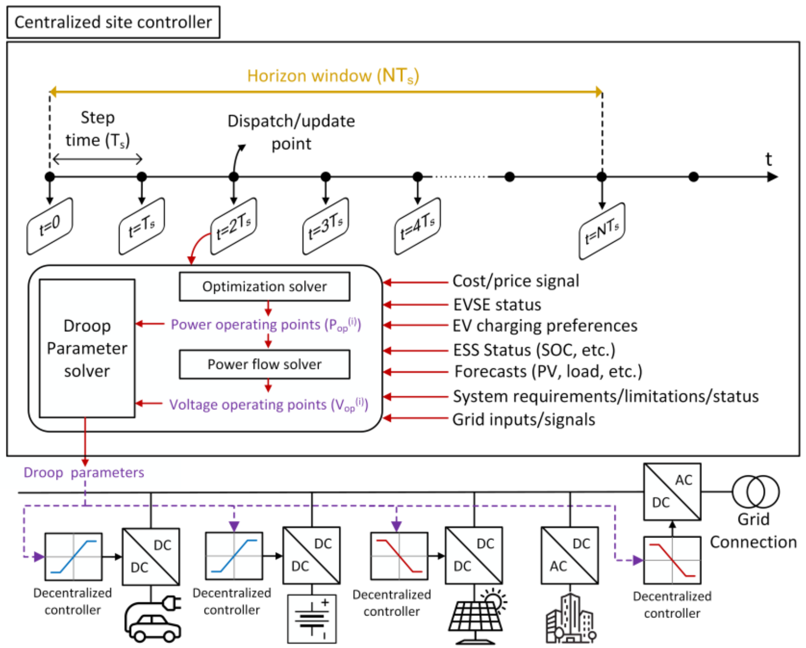
Hybrid Controller



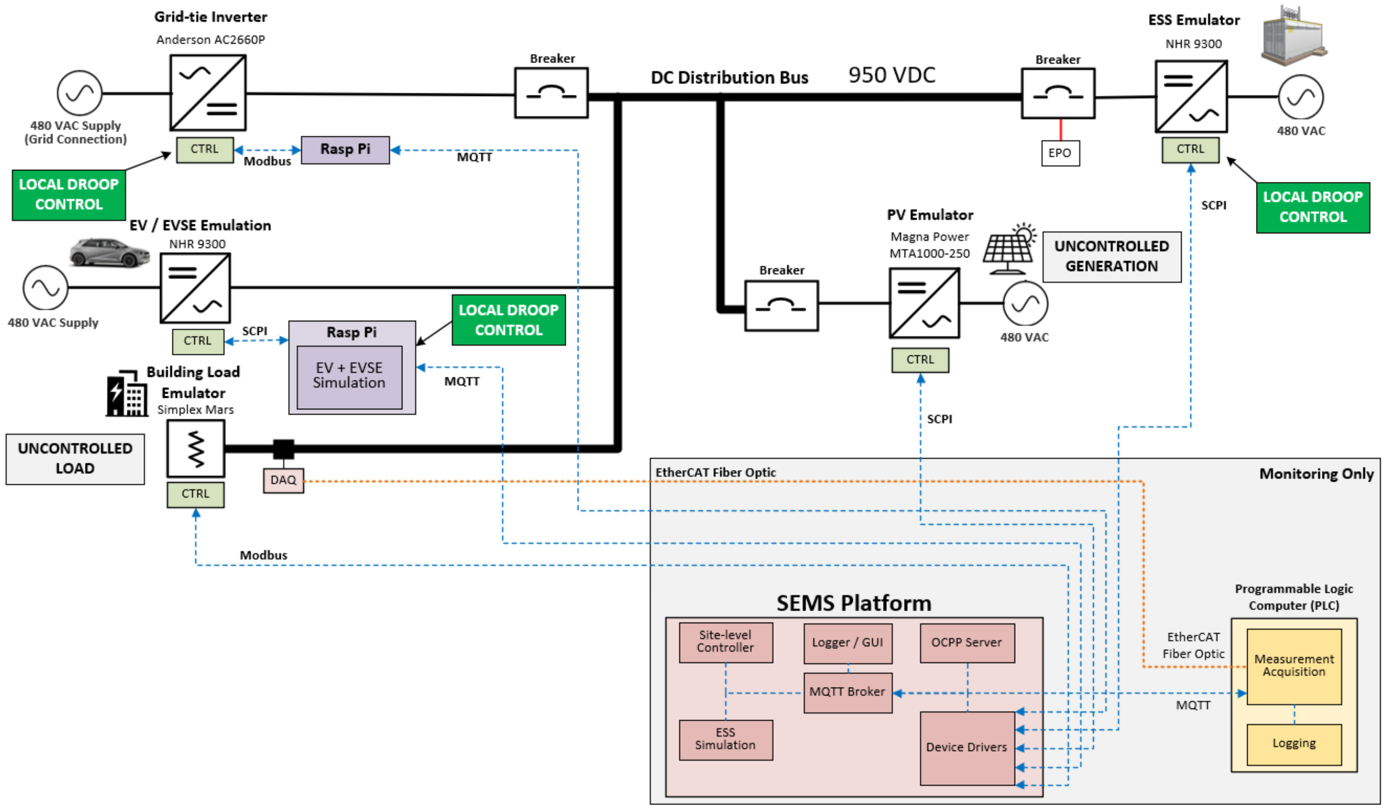
- Multi-layer, hierarchical
- Maximizes longer term operational benefits
- Maintains robustness and fast response
- Reduces communication need
- Requires forecasting

[2] E. Ucer, et al. “Controller Hardware-in-the-loop Modeling and Operation of a High-power DC Charging Hub,” ECCE, Oct. 2023

[3] E. Ucer, et al. “Hybrid Energy Management with Real-Time Control of a High-Power EV Charging Site,” ECCE, Oct. 2024, to be presented.

Experimental Implementation: Decentralized Droop Control

- Droop controllers implemented at each DC hub node.
- Inverter and ESS set a bus voltage reference in response to their measured output current.
- EVSE sets a charging power limit in response to its measured bus voltage.
- PV and building load operate as uncontrolled generation and load.



Anderson AC2660P (GTI); NHR 9300 (EV/EVSE Emulation); Simplex Mars (Building Load); Magna Power MTA1000-250 (PV Emulation); NHR 9300 (ESS Emulation)

Decentralized Droop vs Centralized Rules-based Control

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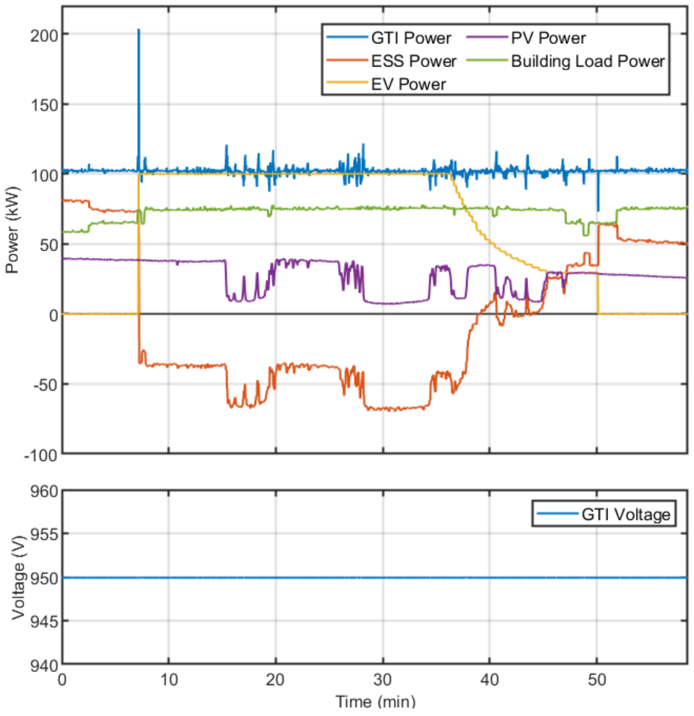
- With droop control, there is no centralized controller.
- Local controllers implement their respective droop functions, and DC hub operates <u>autonomously</u>.
- In rule-based control, a centralized controller continually dispatches the ESS power in response to the measured loads and generation.

Centralized Rule-based Control

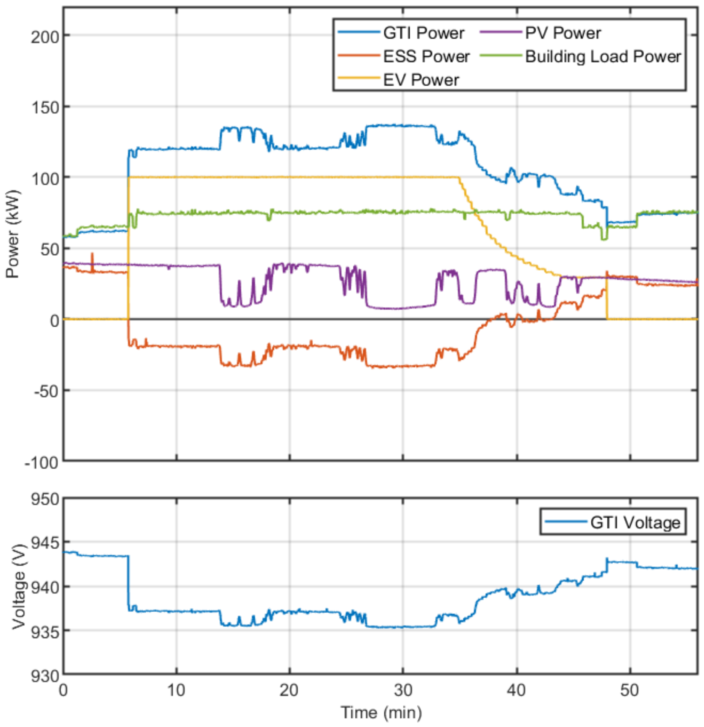
- Ensures equipment is fully utilized
- Requires communication
- Slower response to transients

Decentralized Droop Control

- No real-time site-level communication or central controller required
- Improved resiliency
- Very fast transient response
- Cannot achieve optimal energy management and full site utilization
- Connected equipment must tolerate a range of bus voltages (swinging bus voltage)



Centralized Rule-based Control



Decentralized Droop Control

Conclusion and Next Steps

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Conclusions and Demonstrated Benefits

- DC Hub experimental test platform combines an open-source SEMS with a DC-coupled hardware system.
- Various controller architectures have been evaluated.
- Hybrid control approach optimizes long-term operations while simultaneously enhancing autonomy, robustness, and responsiveness through its voltage-based droop control.
- Droop-control has been demonstrated successfully on DC hub on grid-tie inverter, emulated ESS and EVSE.

Next steps

- Implementation of hybrid controller on experimental platform
- Scaling up C-HIL platform using larger RTS within **ARIES**
- Continued focus on demonstration on various real-world use cases

Thank You!

Join us for the

HPC Deep Dive on

Tuesday November 12, 2024

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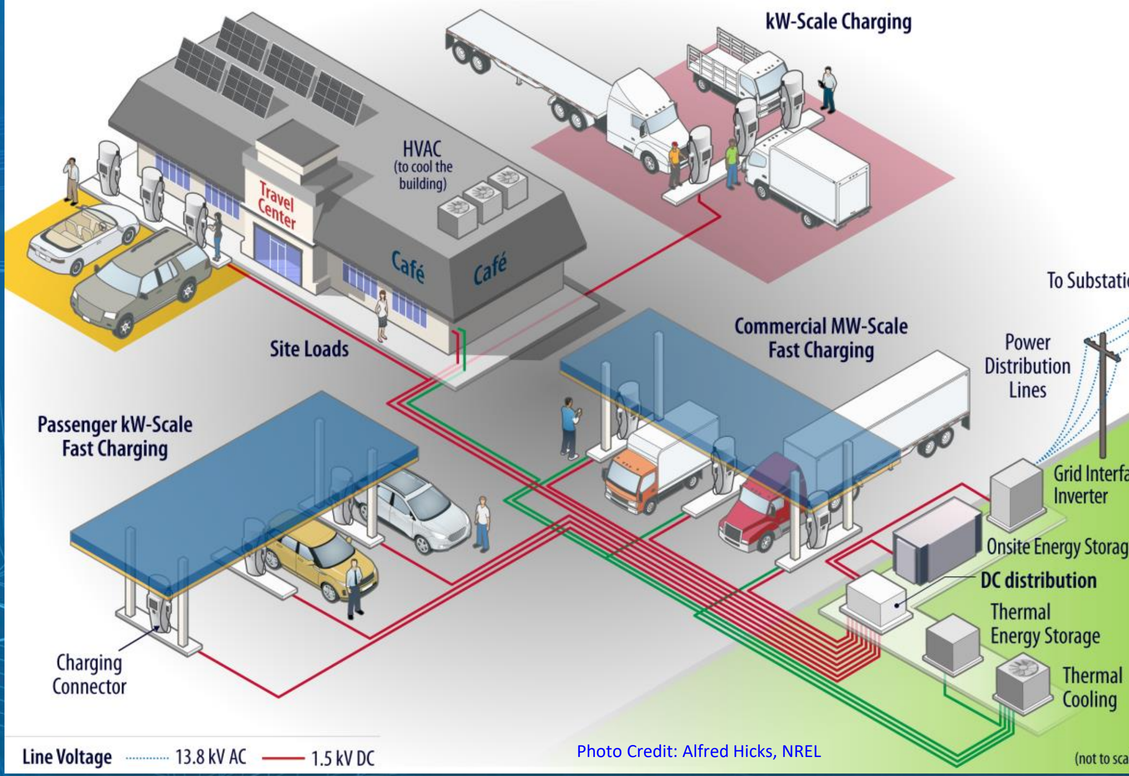

Photo Credit: Alfred Hicks, NREL