EV-Grid Integration (EVGI) Control and System Implementation

Research Overview

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Outline

1. EVGI Research Capabilities
2. Charging management with Renewables
3. PEV charging characterization
4. Microgrid implementation of PEVs
5. Analysis of WPT stationary and in-motion charging
6. Conclusions

Source, NREL.gov

NREL Scope of Work

Systems Integration

- Grid infrastructure
- **Transportation**
- DG interconnection
- Battery and thermal storage

Renewable Energy

- Solar
- Wind and water
- Hydrogen
- Biomass and geothermal

Energy Efficiency

- Residential buildings
- Commercial buildings
- Personal vehicles
- Commercial vehicles

Market Focus

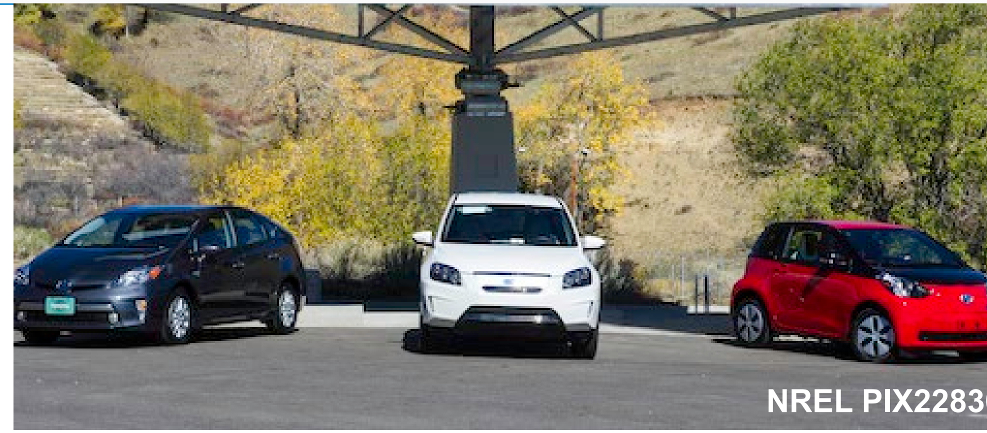
- Private industry
- Federal agencies
- State/local govt.
- International

NREL PIX19929

Image via shutterstock

Vehicle Testing and Integration Facility (VTIF)

VTIF provides interior and exterior areas for systems EVGI communications and power exchange



18kW Solar PEV Parking Lot

NREL Parking Garage with 36 EVSE's Charge Research and Visiting Vehicles

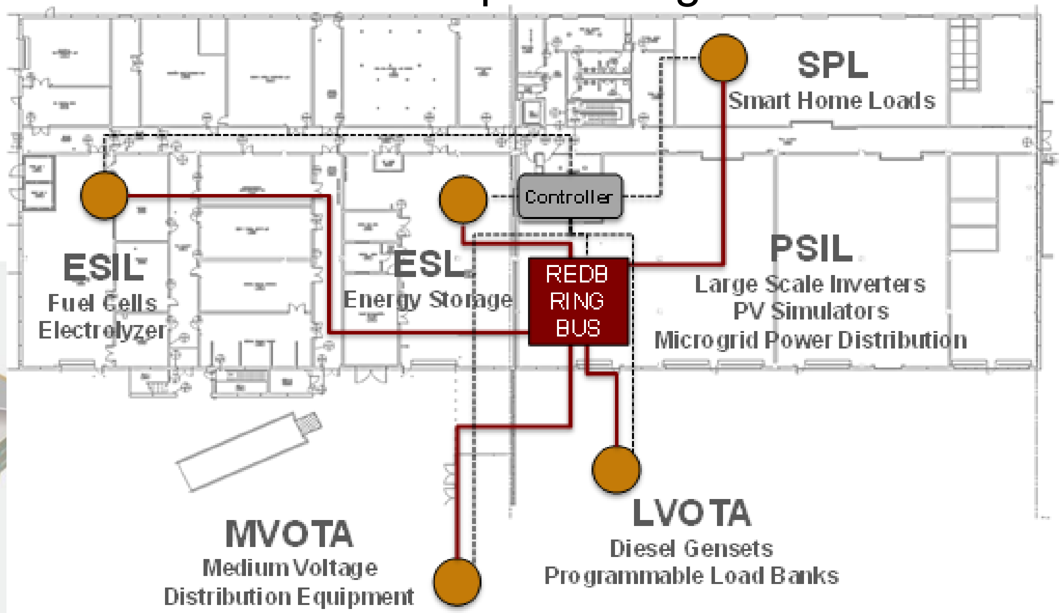
Energy Systems Integration Facility

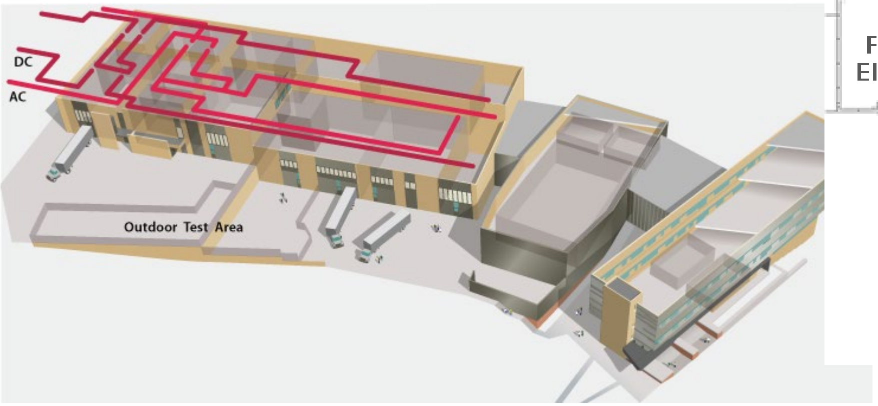
- 182,500 sq. ft.
- 1-MVA bi-directional grid simulator
- Low Voltage Distribution Bus
- Medium Voltage Outdoor Test Area
- Full Power Hardware in the Loop (PHIL) testing
- Petascale High Performance Computing (HPC)

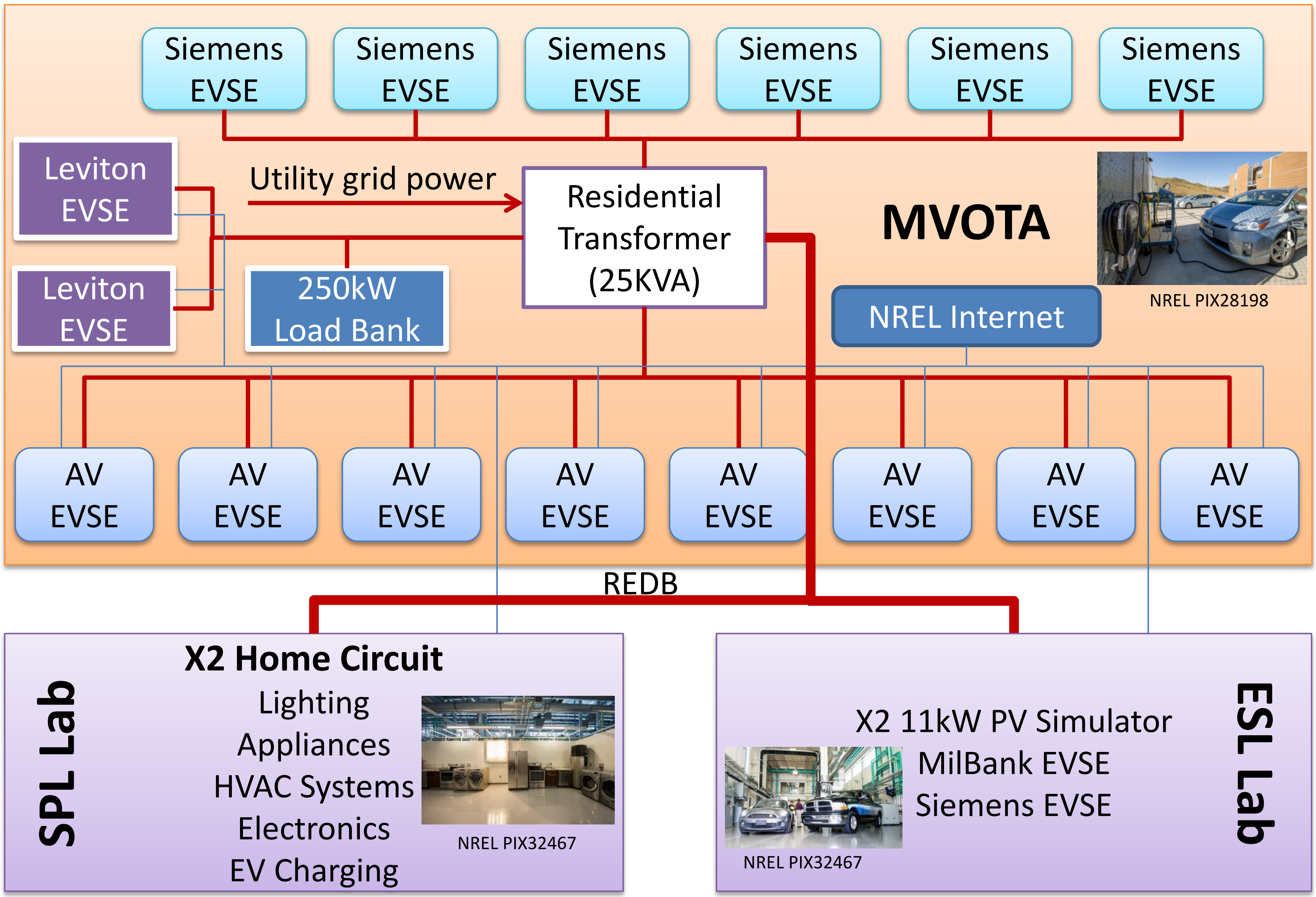
Research Electrical Distribution Bus (REDB)

AC (600 V)	**DC** (±500 V)
• 250 A	• 250 A
• 1600 A	• 1600 A

Example microgrid



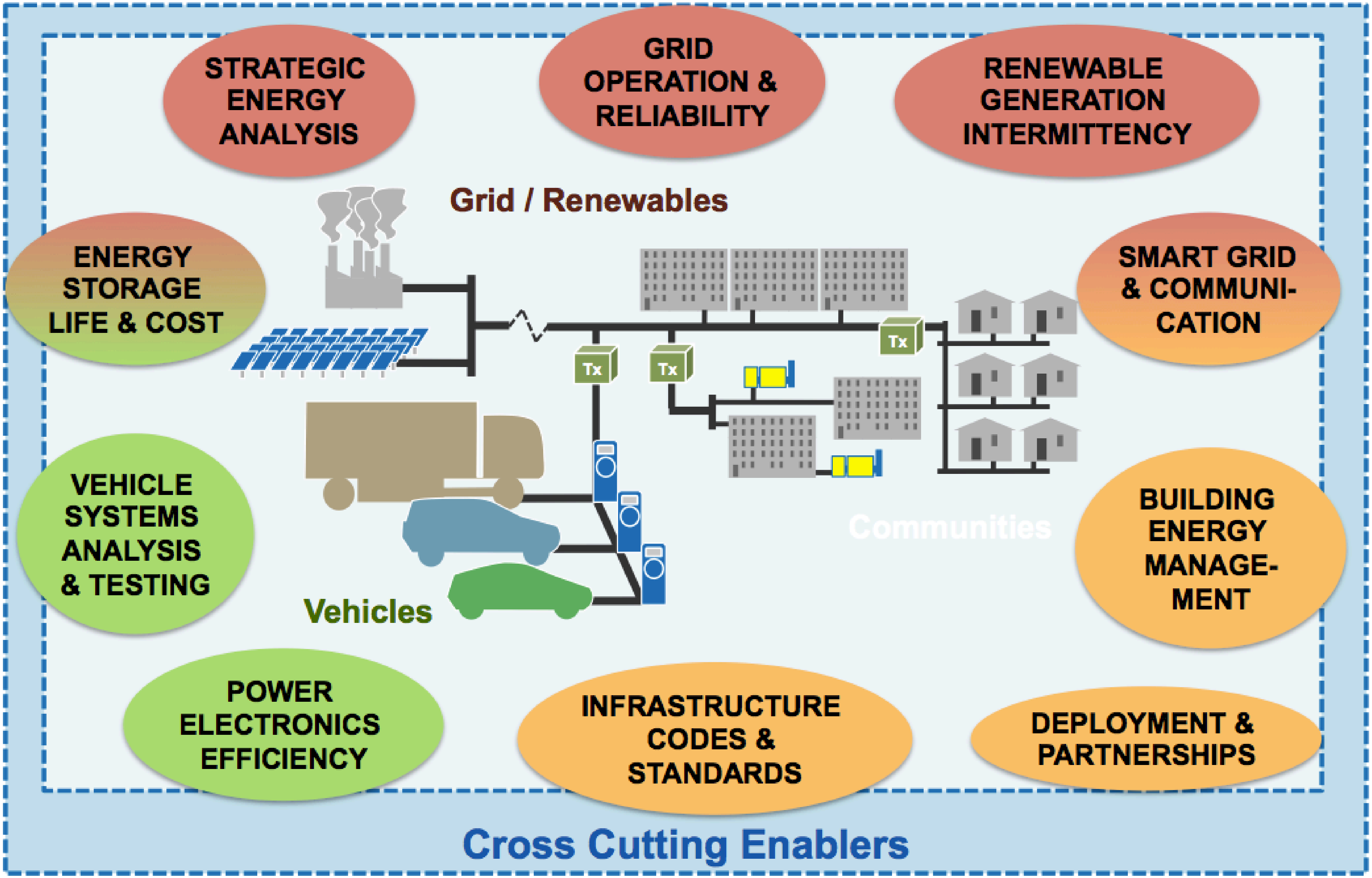




MVOTA: Medium Voltage Outdoor Testing Area
SPL: Smart Power Laboratory
ESL: Energy Storage Laboratory
REDB: Research Electrical Distribution Bus

Communication line
Power line
REDB

Electric Vehicle Grid Integration Framework



Achieved
In Process

Electric Vehicle Grid Integration at NREL

Vehicles, Renewable Energy, and Buildings Working Together

Managed Charging

Evaluate functionality and value of load management to reduce charging costs and contribute to standards development

- ★ GE Wattstation in NREL Parking Garage
- ★ Grid2Home EVSE and Gateway with SEP2.0
- ★ Leviton with Modbus
- ★ AV EVSE via Wifi

Local Power Quality

Leverage charge system power electronics to monitor and enhance local power quality and grid stability in scenarios with high penetration of renewables

- ★ Toyota collaboration leverages vehicles and ESIF
- ☆ Light and heavy duty wireless charging systems
- ☆ Bi-directional fast charge

Emergency Backup Power

Explore strategies for enabling the export of vehicle power to assist in grid resiliency during outages and disaster-recovery efforts

- ★ Via Motors- export power functionality
- ☆ Nissan Leaf with Nichicon V2H unit to power home-loads

Bi-Directional Power Flow

Develop and evaluate integrated V2G systems, which can reduce local peak-power demands and access grid service value potential

- ★ Mini-E with Univ of Del and NRG
- ★ PGE Utility truck characterization in ESIF
- ★ Via Motors van-Coritech EVSE with grid SEP2.0
- ☆ Smith EV truck

Life Impacts

Can functionality be added with little or no impact on battery and vehicle performance?

- ★ Using BLAST-V for scenario assessment

Information Flow and Control

How is information shared and protected within the systems architecture?

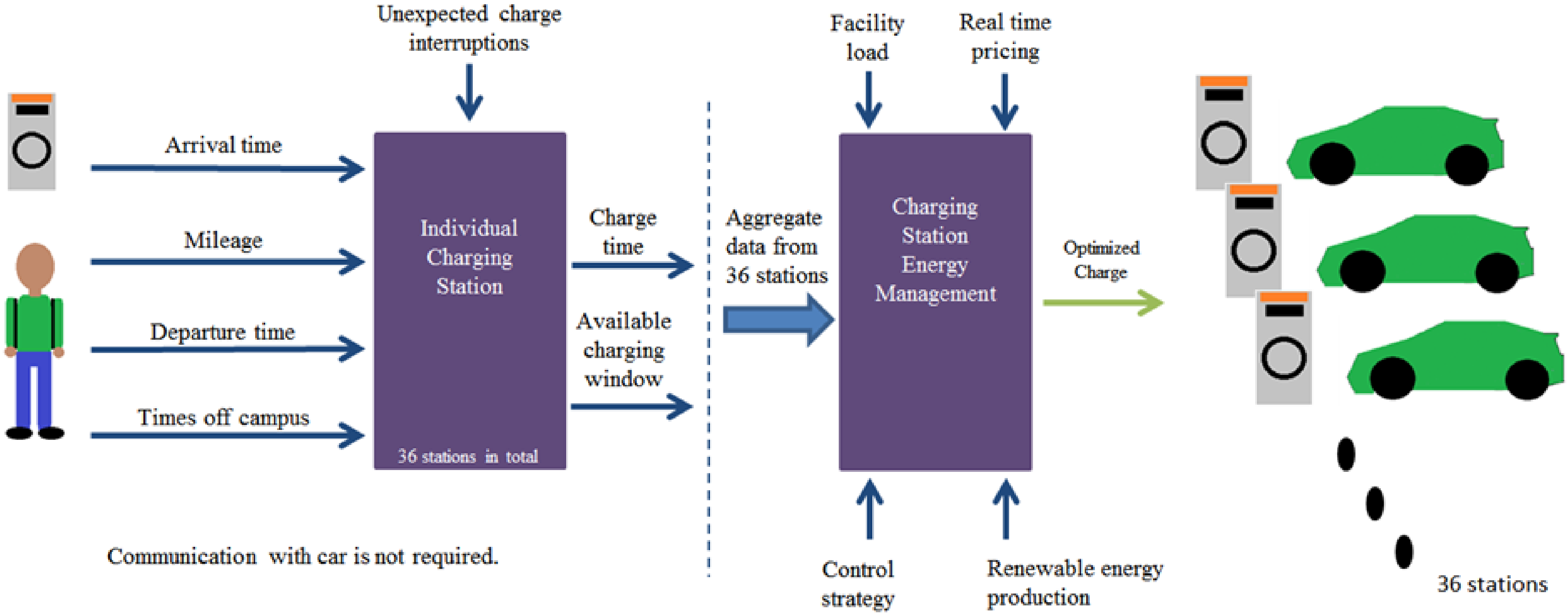
- ★ Developed data entry and campus connections

Holistic Markets and Opportunities

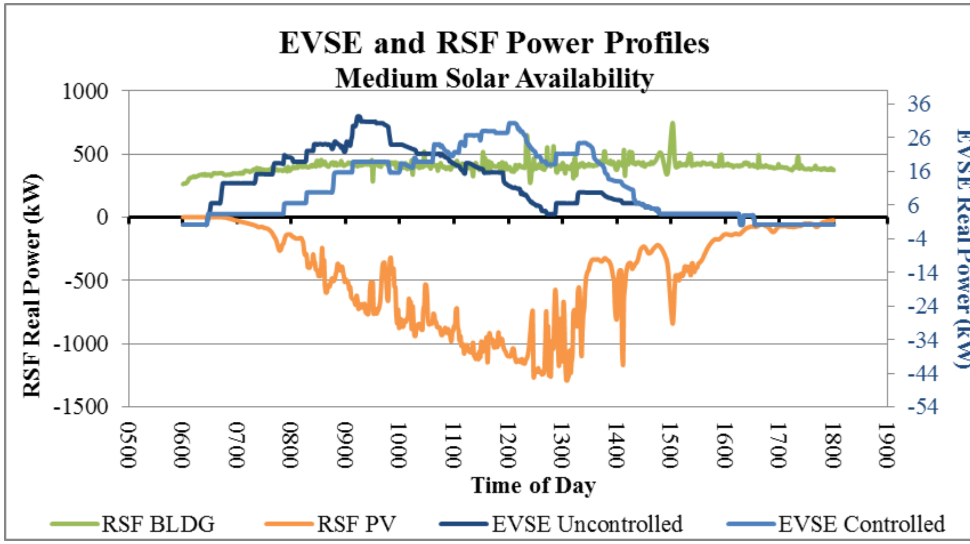
What role will vehicles play and what value can be created?

- ★ SEAC collaboration on market opportunities report

PEV Charge Management with Renewable Sources



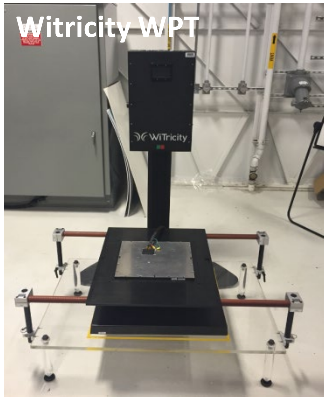
Provide simple interface with least information necessary to create managed individual and aggregate scenarios with status display



RSF = Research Support Facility

AC Microgrid System Component Characterization

- Sharp Energy Storage System: 43 kWh, 30 kW IPC interface
- Via Motors Van - Coritech EVSE:23 kWh, 14.4 kW V2G-V2H
- Nissan Leaf - Nichicon EV Power Station 6kW V2H
- Smith EV Truck-Coritech EVSE: 80 kWh, 60 kW
- WiTricity wireless charging units 3×3.3 kW
- PV System (emulated-22 kW and real-18 kW)
- Residential and commercial loads (125kW AC)
- 30kW Grid Simulator and RTDS system



Source NREL, Andrew Meintz

Smith EV Truck

Source NREL, Andrew Meintz

How to build an MG scenario using these assets?

- *System component modeling, MG central controller design and testing*.

Export Power Using PEVs

Via Motors Van with Coritech EVSE

- 14.4 kW on-board bidirectional charger
- Series hybrid PHEV with 23 kWh battery
- V2H and V2G capable, SEP 2.0 grid link, Homeplug GREEN PHY
- Single phase 120V/240V up to 60A off-grid power generation

Nichicon EV Power Station

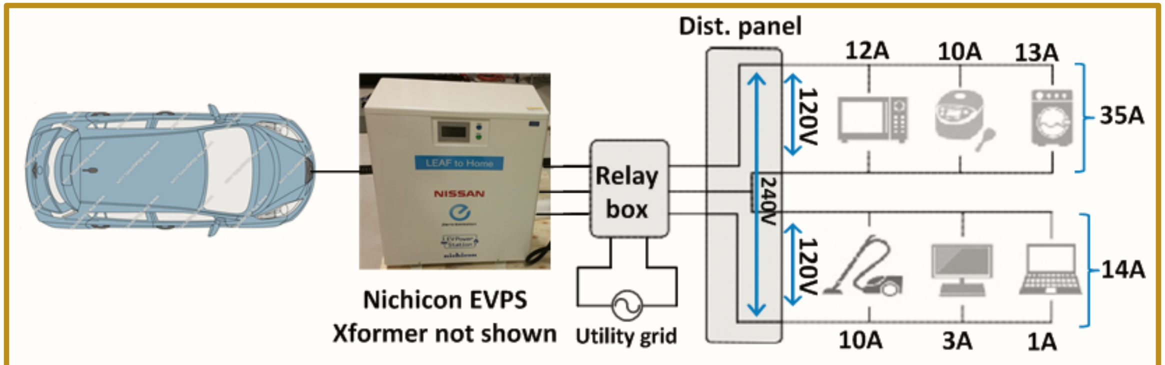
- 6 kW off-board charging capability
- 120V/240V, total 50A@120V V2H power capability
- Runs with Chademo compatible PEVs (Leaf, Mitsibushi i-MiEV)
- Switching from grid connected to grid-isolated operation

Research scope

- Analysis of powering real home loads with Nissan Leaf and Via Van w/o grid.
- Evaluating the emergency power capability of EV (Leaf) and PHEV (Via-Van).
- Integrating emulated/real solar PV systems with V2H to extend the emergency power duration.
- Investigating microgrid operation of vehicles to power several houses.

Via export power port

Source NREL, Mithat Kisacikoglu

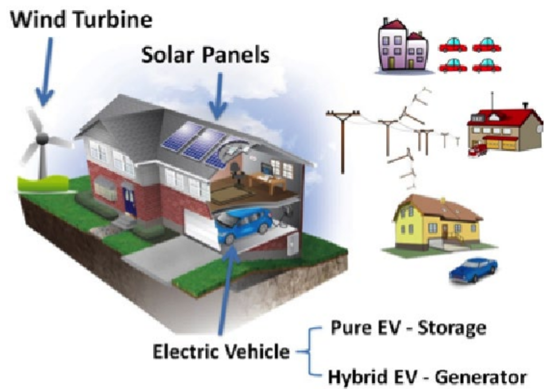


Leaf-Nichicon power export

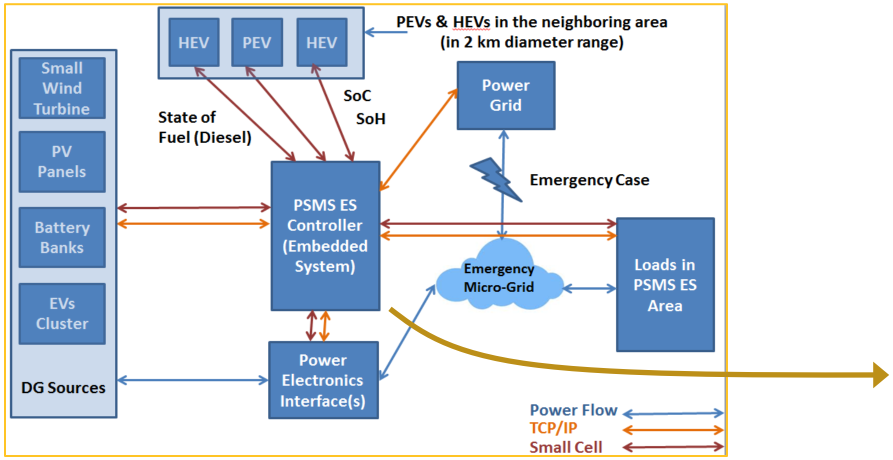
System Modeling for Emergency Operation

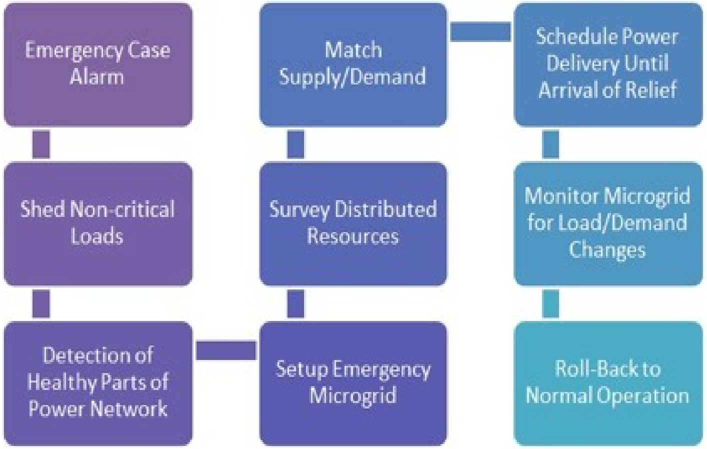
Stages for modeling:

- Switching time simulation of one on/off-board charger
- Daily RMS simulation of utility grid with tens of PEVs
- Real time simulation of developed system
- Controller HIL real-time simulation to test communications and controllers
- Power HIL real-time simulation to validate power flow



Example for emergency power system management scheme:

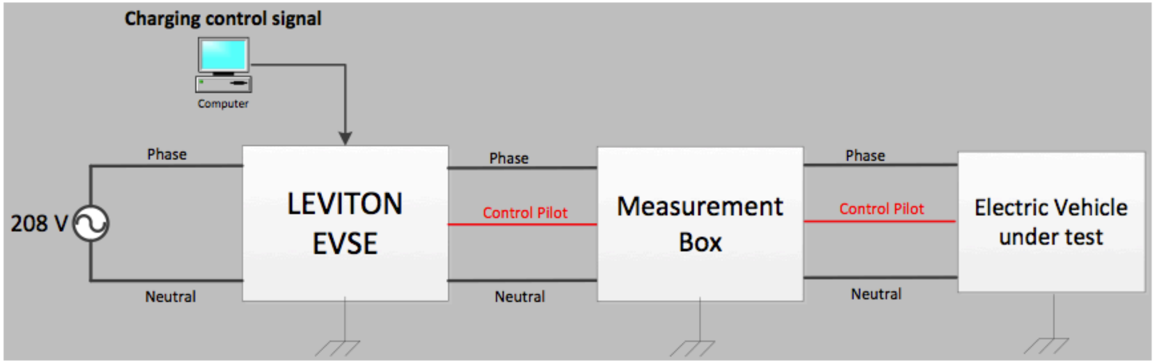


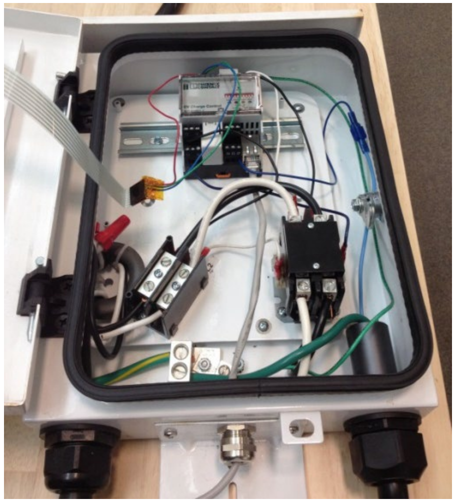


For more info:
T. S. Ustun, U. Cali, **M. C. Kisacikoglu**, "Energizing microgrids with electric vehicles during emergencies - Natural disasters, sabotage and warfare" presented in IEEE INTELEC, Osaka, Japan, Oct. 2015.

On-board Charging Characterization

- Unidirectional control of EVSEs over Modbus using market vehicles:
- 5 to 10 A step-up/down tests to validate dynamic performance





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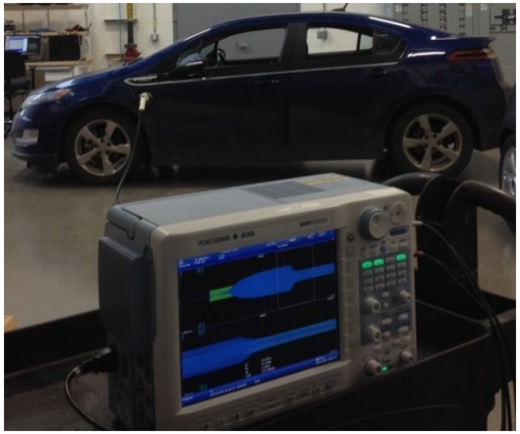

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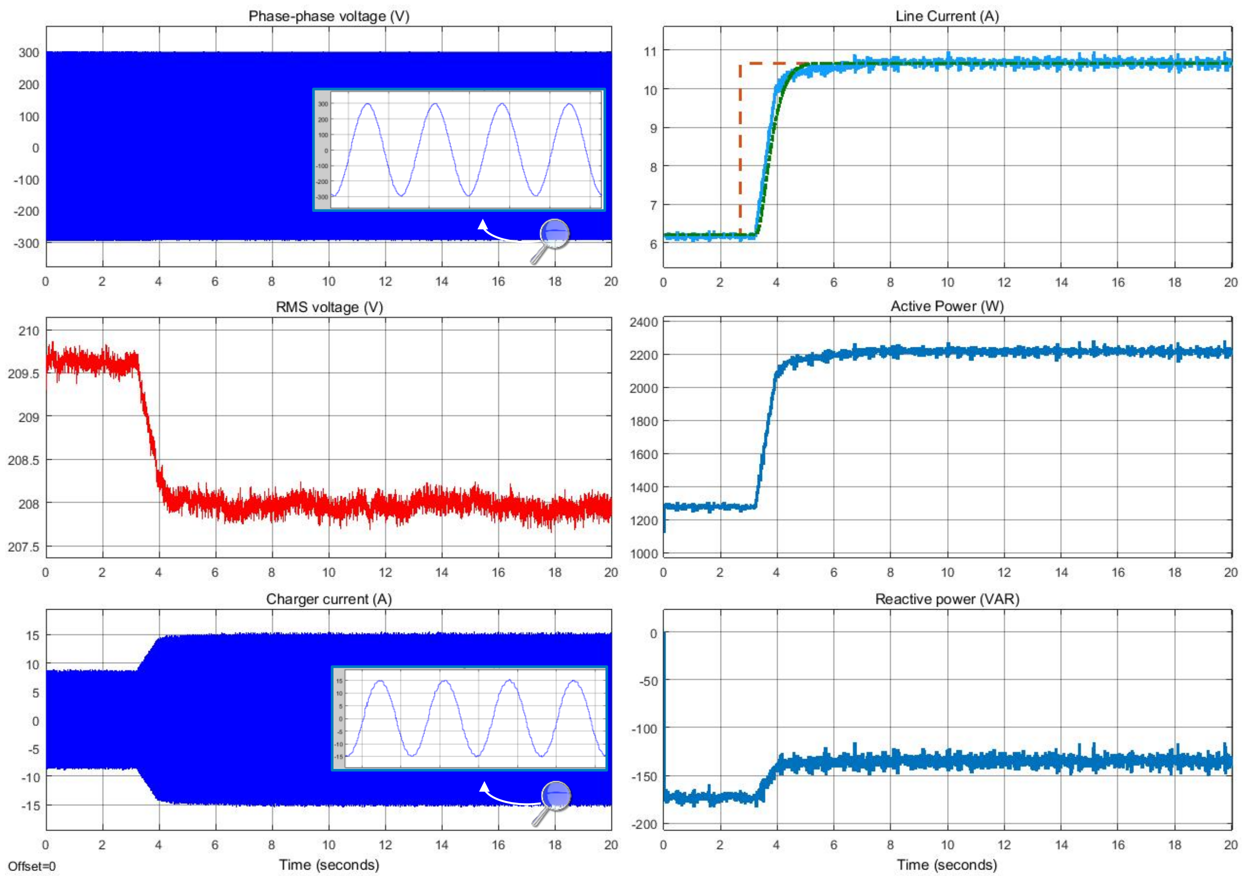
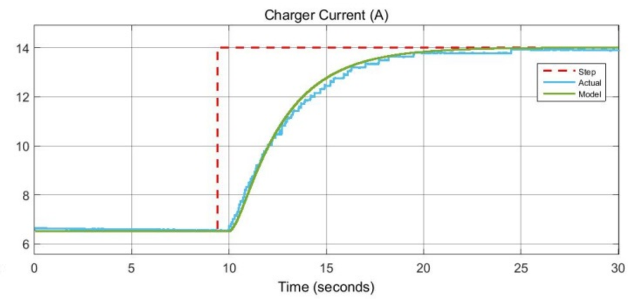
Unidirectional Charging Characterization

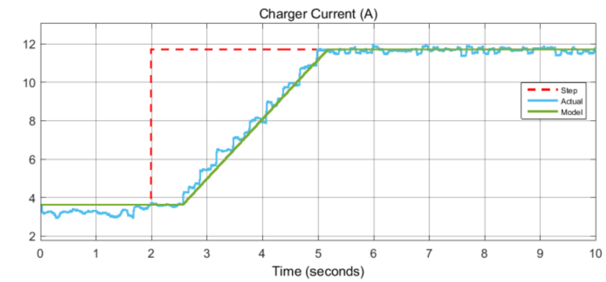
- ~0.56s communication delay using Modbus protocol
- Different vehicles respond with different transfer functions



MY13 Toyota IQ

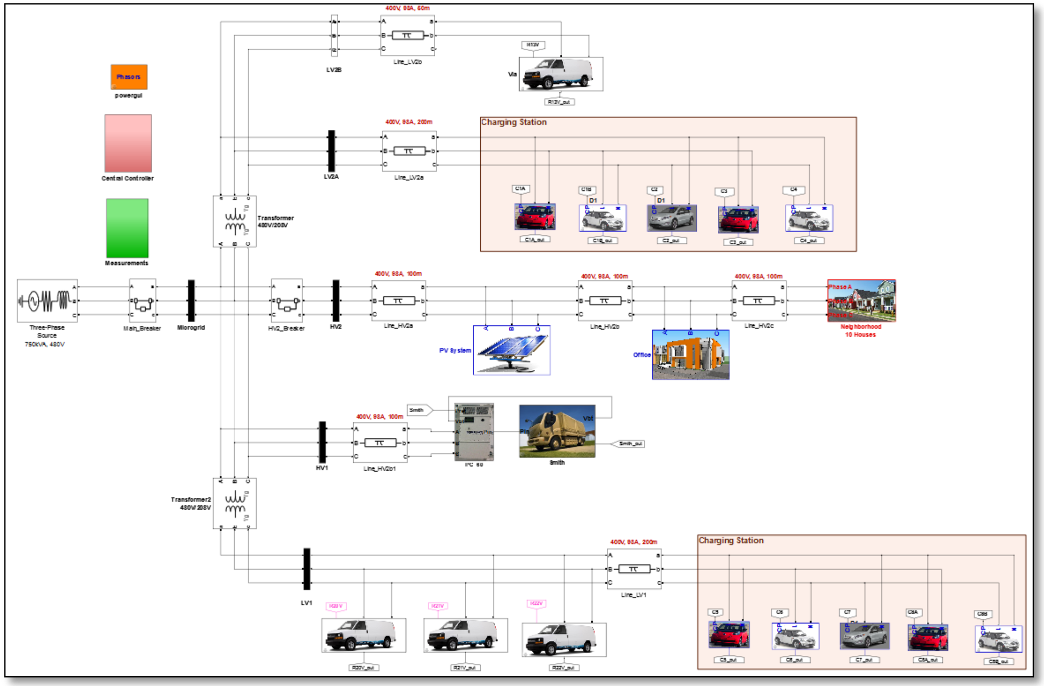


MY13 Chevy Volt



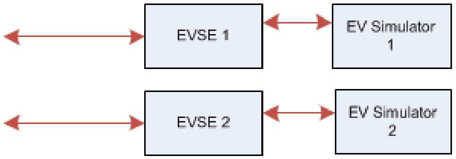
Mini-E

Testing of Microgrid Embedded PEVs

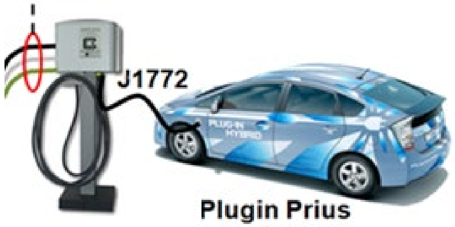


Real-time Simulation

C-HIL Testing

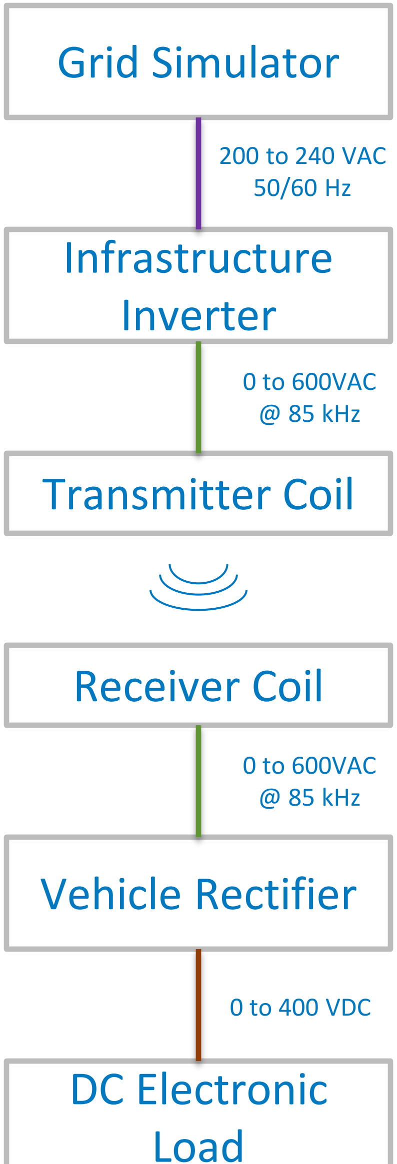


P-HIL testing

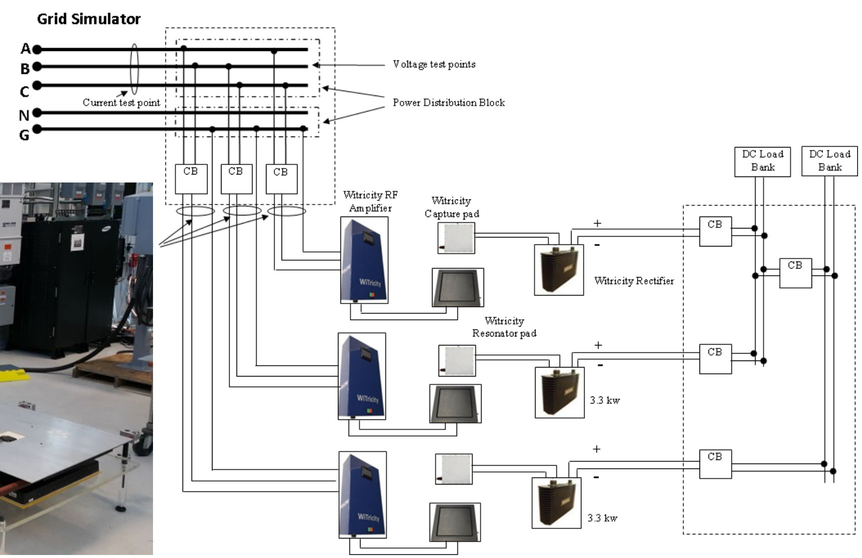


- Communication protocol testing
- Implementation of control through DMS
- Verification of charging/discharging algorithm development.

WPT Grid Integration Testing



- Power quality testing for different grid voltage/frequency, receiver alignment, and battery charging power conditions.
  - Current harmonics
  - Battery ripple current
  - Power factor
- Management with renewable and L2 EVSEs
- Three-phase implementation in a microgrid study.

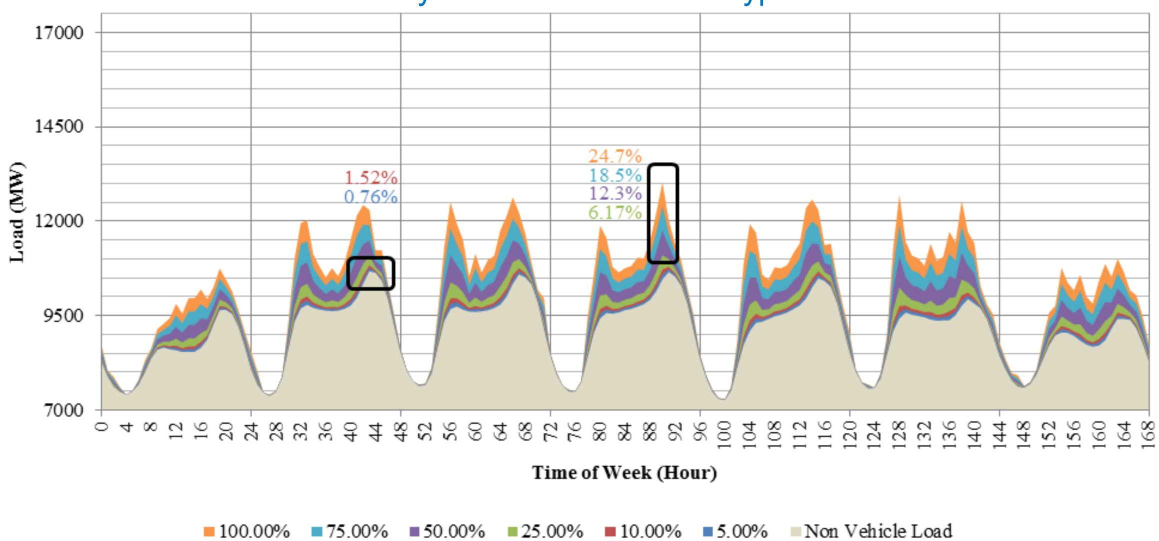


Source NREL, Mithat Kisacikoglu

WPT Grid Impacts Load Shape Analysis

- Grid load for the Atlanta region was determined from the power consumed by the transmission zones in the 2013 Atlanta CSA - Eastern Renewable Generation Integration Study (ERGIS) developed by NREL
- The grid load for the four seasons have been determined by averaging the hourly load throughout a week for each hour within the season.
- For the graphs, the numbers in colored text indicate the percent load growth over the baseline at the new seasonal average load peak resulting from each fractional VMT electrification scenario.

Electrified Roadway Scenarios added to Typical **Fall** Grid Load



Electrification of 5% of light-duty VMT results in a load growth between 0.70% and 1.16% for the peak load hour

typical utility load growth 1-1.5%/yr

A. Meintz, J. Gonder, J. Jorgenson, and A. Brooker "Analyzing potential grid impacts from future in-motion roadway wireless power transfer scenarios" to be presented in EVS29, 2016

Conclusions and Future Work

- Framework of EVGI infrastructure described.
- EVGI includes not just power electronics but also communication, standards, signal processing, grid-level control, and distribution modeling.
- Each PEV model has different EVGI response characteristics during grid-interaction.

Future work:

- Development of an EVGI C-HIL and P-HIL testing platform
  - Verification of grid-level EVGI control development
  - Implementation of SEP2.0 communication for V2G signals
  - Distribution system impact analysis of V1G, V2G, and V2H (Black-start)
- Wireless charging
  - Multi-unit testing of static WPT systems for grid impact analysis

Energy Benefits from Vehicles, Buildings, and Renewables Working Together

Questions

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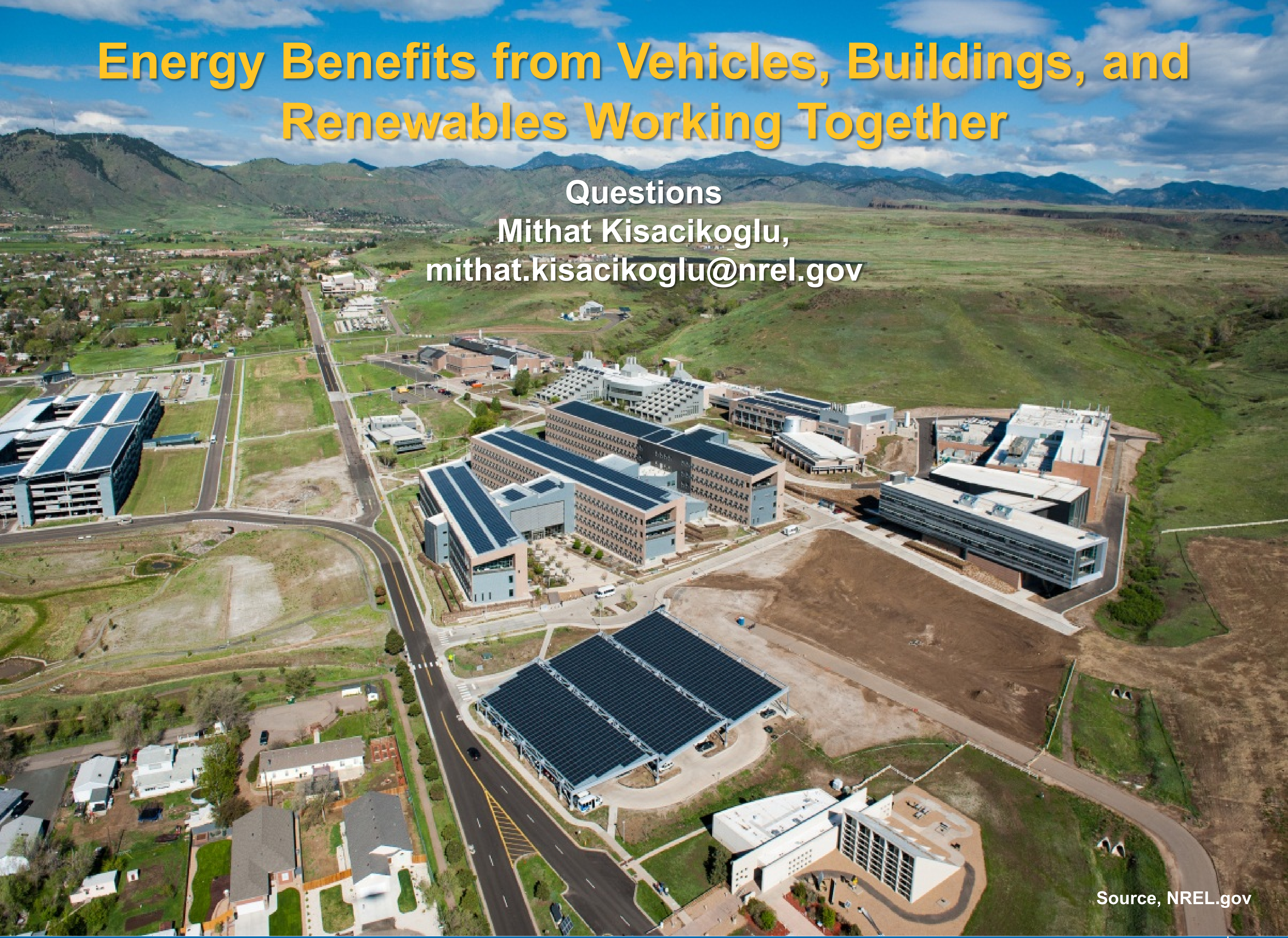

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