VTO Systems Research Supporting Standards and Interoperability

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2016 Annual Merit Review

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INL/MIS-16-38399

Project ID VS182

Overview

Timeline

- Project start: April 1, 2016
- Project end: Sep 30, 2018
- Percent complete: 5%

Barriers

- Infrastructure – can plug-in electric (PEV) vehicle/grid integration (VGI) benefit vehicle consumers and electric utilities?
- Risk aversion - understand and avoid risks vehicle/grid integration poses to vehicle consumer, vehicle, and grid
- Lack of standards – research is needed to support development of the multitude of standards necessary to facilitate vehicle/grid integration

Budget

FY16

- $ 1,180K to National Labs
- $ 100K to Siemens

FY17

- $ 1,020K to National Labs
- $ 80K to Siemens

FY18

- $ 1,020K to National Labs
- $ 80K to Siemens

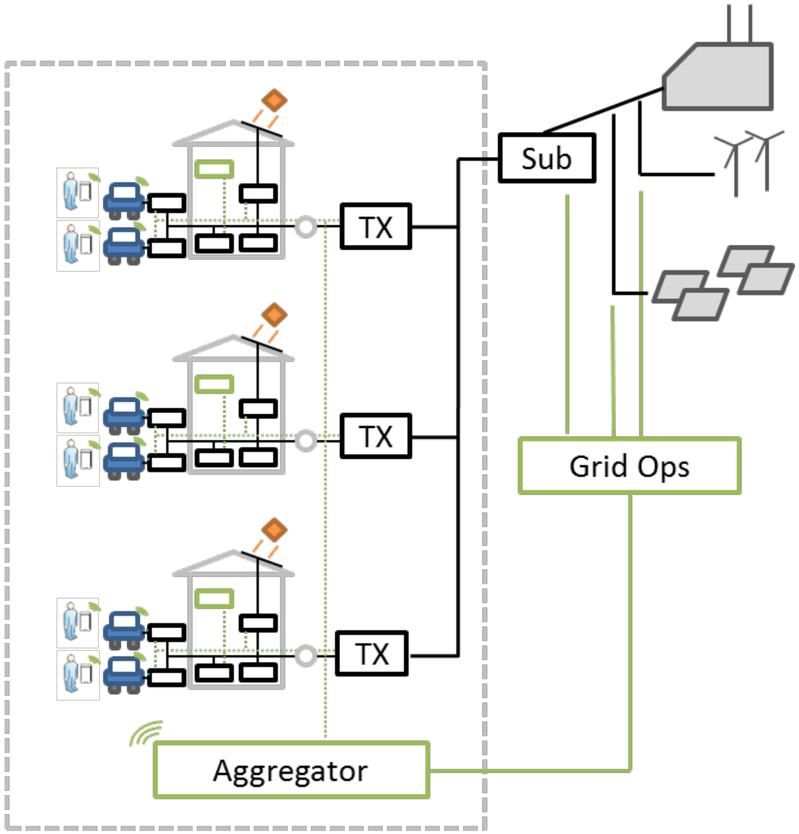
Partners

- Project lead: INL
- Partner labs: ANL, LBNL, NREL, PNNL
- Industry partner: Siemens
- Advisory board: Bonneville Power Administration, Duke Energy, DTE Energy, Eversource Energy, University of Delaware, and California Energy Commission, USDRIVE Grid Interaction Technical Team industry partners

Project Objectives/Relevance

Overall Objective

- Determine the feasibility of PEVs providing grid services and renewable energy integration at the electric utility distribution level without negatively impacting grid stability or the PEV customer experience
- Develop a hardware-in-the-loop (HIL) platform to demonstrate integration of numerous vehicles with distributed energy resources at numerous facilities
- Trial multiple communications pathways to accelerate standards development and understand how to prioritize the needs of the PEV customer, facility, third-party aggregator, and grid operator in multiple use cases



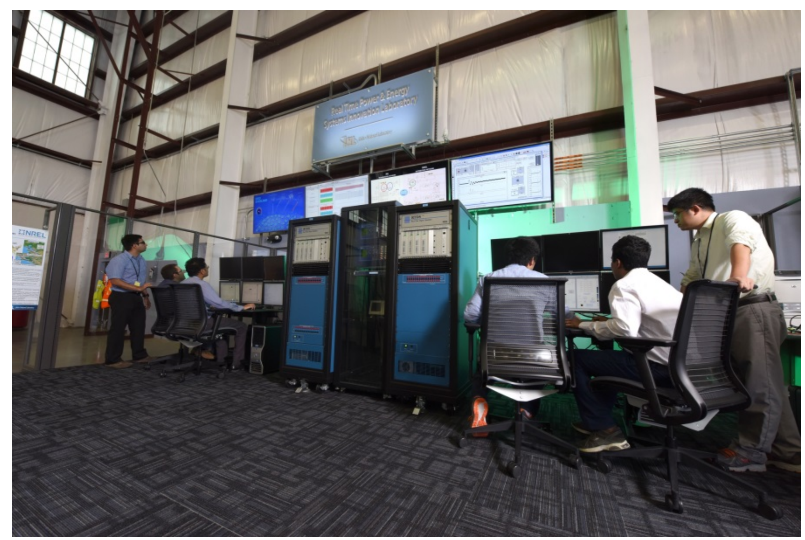
Relevance to Barriers

- Develop and validate a control strategy to integrate the **infrastructure**, **avoid risks** of negative interactions, and prove out **standards** under development

Approach/Strategy

Develop a HIL platform that emulates an electric utility's distribution network, including a large number of PEVs and other distributed energy resources at numerous facilities

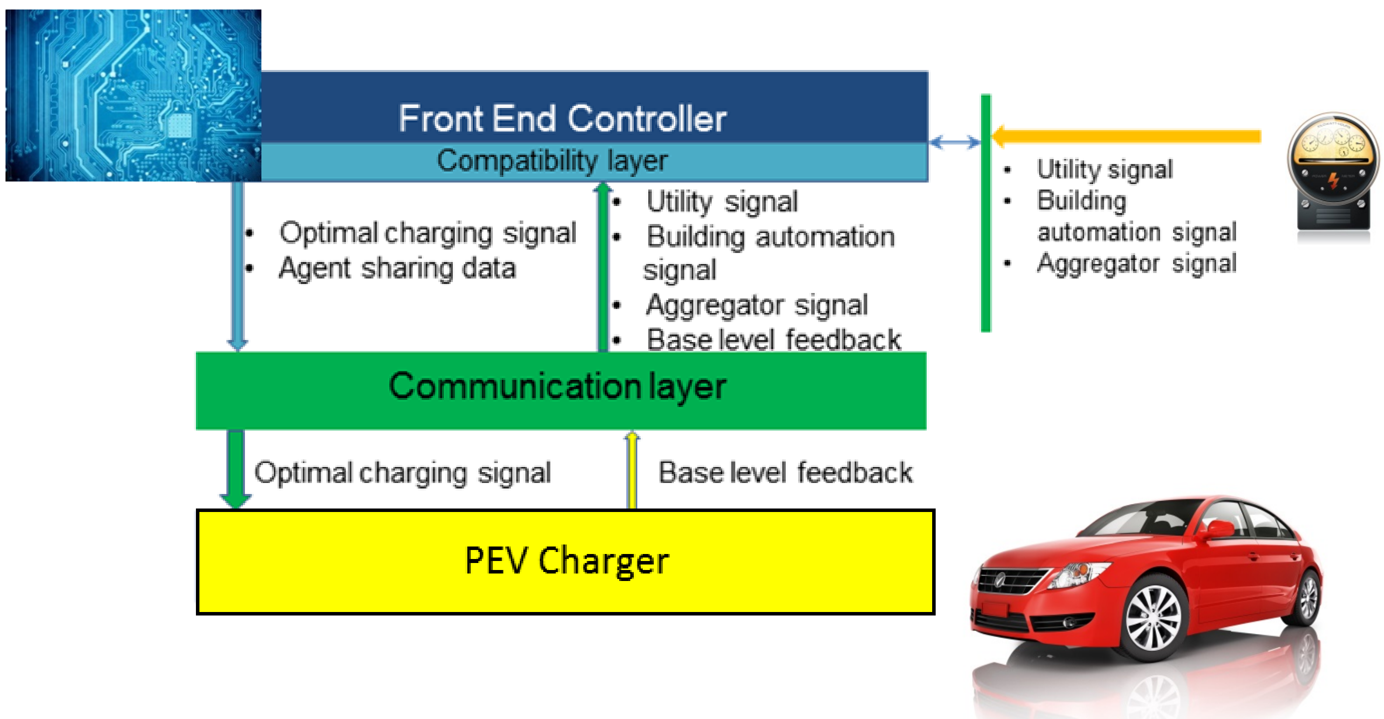
- Use power-HIL to characterize vehicle charging profiles under a wide variety of grid conditions and develop high fidelity models for vehicle emulation
- Emulate communications hardware with realistic latencies and protocols representative of standards under development
- Integrate actual control system hardware (controller-HIL)
- The platform will be based on dynamic real-time simulation (DRTS), which performs low-level physics modeling of the electrical system (micro-second resolution)
- This approach is the most accurate way to study electrical system dynamics, short of a real-world distribution network demonstration (cost prohibitive)



Approach/Strategy

Use the HIL environment for rapid controls development to understand how to prioritize the needs of the PEV customer, facility, third-party aggregator, and grid operator in multiple use cases

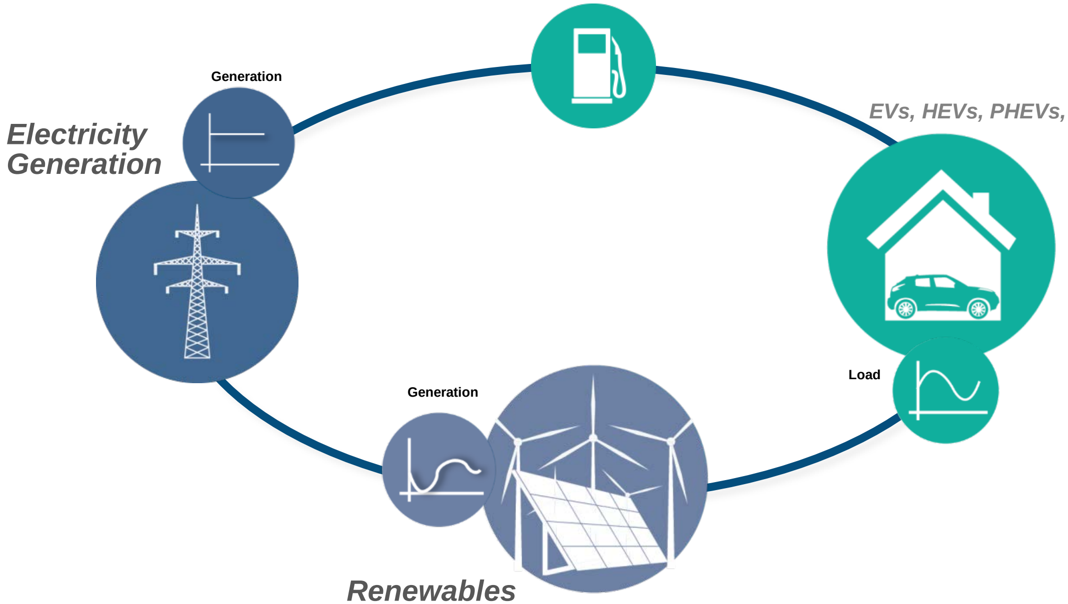
- Develop a front-end controller (FEC) to enable coordination of PEV charging with signals from the utility, aggregator, and Distribution Management Systems (DMS)
- Generate and send transactive signals to FECs based on multiple likely scenarios



Approach/Strategy

Verify the viability of controlled PEV charging to facilitate renewables integration and other valuable grid services

- Perform experiments that emulate distribution-level VGI in a variety of use cases
- Understand the impact of controlled charging on distribution network system dynamics, power quality, and stability
- Understand the ability of the system to provide grid services, while still meeting the PEV owner's requirements for charging



Approach/Strategy

Expected Outcome and Benefits

- Provide open communication and control architecture developed by this project as a benchmark for industry
- Share findings directly with standards development committees
- Enable quicker, cost-effective prototyping, as well as mitigation of potential risks associated with PEVs being interconnected to the grid
- Help business planners and policy makers make informed decisions about the effort required and potential benefits of building the infrastructure necessary to enable PEVs to provide grid services
- Enable VGI to help the electric utility industry manage increasing electricity demand, optimize utilization of existing generation, and integrate renewable.
- Possibly provide a new value stream to PEV owners, thus benefitting PEV customers, auto makers, and the large number of stakeholders who are promoting PEV adoption

Approach/Strategy

Relationship to other projects

This is one of three projects that will collaboratively demonstrate PEV charging as an integral part of the smart, renewable electricity grid of the future

- This project (*GM0085*) and *GM0062 Vehicle to Building Integration Pathway* are complementary and specifically designed to target different grid domains
  - *GM0062 Vehicle to Building Integration Pathway*, led by PNNL, will focus on behind-the-meter integration of PEVs at a single facility, including demonstration with real hardware in an integrated testing environment
  - GM0085 will validate interface requirements between components of the system developed in *GM0062 Vehicle to Building Integration Pathway*, with respect to system interactions at the distribution level
- GM0085 also will be coordinated with *GM0086 Modeling and Control Software to Support V2G Integration*, led by LBNL, which is focused on higher-level modeling to understand market dynamics and economic impacts
  - High-potential use cases and controls methodologies will be cascaded from GM0086 to GM0085 for low-level controller implementation and evaluation of electrical systems dynamics

Approach/Strategy

Relationship to other projects

The scope of this project overlaps with several Grid Modernization Laboratory Consortium foundational projects

- The following are foundational topic areas relevant to this project:
  - *1.4.1 Standards and Test Procedures for Interconnection and Interoperability*
  - *1.4.2 Definitions, Standards and Test Procedures for Grid Services from Devices*
  - *1.2.3 Establishment of Grid Modernization Laboratory Consortium – Testing Network (GMLC–TN)*
  - *1.4.11 Multiscale Integration of Control Systems (EMS/DMS/BMS)*
- In each case, foundational work will provide guidance, but not final solutions for the specific work addressed by this project
- Project researchers will be careful to stay abreast of these projects' findings to avoid duplication of effort

Milestones – FY16

Milestone Name/Description	End Date	Type
Finalize development of vehicle charging demonstration use cases, communication pathways to be emulated, control requirements, and testing processes needed to demonstrate control of PEV charging and assess impact on PEV owner and the grid distribution network	10/1/16	Annual Milestone

Go/No Go Decision	Criteria	Date
Consensus reached on uses case and communication/control pathway selection	The project team shall have selected and documented the use cases and communication/control pathways that will be studied in the HIL environment. The industry partners shall verify that these uses cases and communication/control pathways are relevant to industry needs.	10/1/16

Milestones – FY17

Milestone Name/Description	End Date	Type
INL's power hardware in the loop (PHIL) / controller hardware in the loop (CHIL) environment is developed and operational	4/1/17	Semi-annual milestone
A study of uncontrolled charging is completed using the dynamic real-time simulation (DRTS) with simulated distribution network, PEV charging system characterization models, and simple PEV state models	10/1/17	Annual Milestone

Go/No Go Decision	Criteria	Date
Front-end controller (FEC) developed and verified	FEC operational and verified to meet requirements developed in Year 1	10/1/17

Milestones – FY18

Milestone Name/Description	End Date	Type
Completion of VGI study of at least 3 use cases, in which PEV charging is controlled to provide grid services.	4/1/18	Semi-annual milestone
Completion of assessment of impact on controlled PEV charging on the PEV owner and the grid distribution network	10/1/18	Annual Milestone

Go/No Go Decision	Criteria	Date
Determination of benefit of controllable charging	Controllable charging shall provide measurable benefit over base uncontrolled charging case in order to proceed with PEV owner impacts assessment	4/1/18

Accomplishments

- National labs have identified and down-selected demonstration use cases and communication pathways to be emulated
- INL and Siemens have specified requirements for Smart Energy Box integration with INL's DRTS and procurement process has started
- INL developed controllable electric vehicle supply equipment and demonstrated connection with DRTS for vehicle charging characterization
- INL has completed work plan for vehicle charging characterization, including timeline for vehicle shipments from subcontractor*

  * this project will make use of several different make/model PEVs being tested under DOE's Advanced Vehicle Testing Activity

Collaboration and Coordination with Other Institutions

- Partner labs will lead specific tasks in their areas of expertise, summarized as follows:
  - All five labs will work together to select common use cases and communication pathways
  - **ANL**: communications requirements, hardware, and dissemination of results to standards committees
  - **LBNL**: aggregator-level control requirements; PEV state model integration; PEV owner impacts assessment
  - **NREL**: development of power-HIL platform at NREL with DERs that interfaces with INL's system; distribution-level grid simulation requirements; FEC verification and evaluation of controlled PEV charging; PEV owner impacts assessment
  - **PNNL**: aggregator-level control requirements; control agent selection and integration; technical support for agents and models during evaluation of controlled PEV charging
- **Siemens**: provide Siemens Smart Energy Box and supports development of controls interface between DRTS, FEC, and DMS/aggregator models
- **Advisory Board**: review use cases and communication pathway selection; review interim and final results of control strategy and PEV owner impacts

Remaining Challenges and Barriers

Future challenges and barriers are consistent with the initial project work scope

Proposed Future Work

FY16 tasks

Year 1: Scenario Development and HIL Environment Implementation			Apr	May	Jun	Jul	Aug	Sep
1	INL, ANL, LBNL, NREL, PNNL	Use case scenario and communication pathway selection						
1.2	Advisory Board	Use case and communication pathway review and finalization						
2.1	INL, NREL	Distribution-level grid simulation development						
2.2	LBNL, PNNL	Aggregator-level control definition and agent development						
2.3	ANL	Define technical requirements for emulated communications						
2.4	INL, PNNL	Communication agent creation						
2.5	INL	Simple PEV state model agent creation						
2.6	INL	Integration of agents with grid simulation in DRTS						
3	INL, Siemens	FEC hardware integration with DRTS						
4.1	INL, NREL	PEV charging system connection to DRTS						
4.2	INL	PEV charging system characterization						

Response to Previous Year Reviewer's Comments

This project was not reviewed last year

Summary

Relevance

- Determine the feasibility of PEVs providing grid services and renewable energy integration at the electric utility distribution level without negatively impacting grid stability or the PEV customer experience

Approach

- Develop a hardware-in-the-loop (HIL) platform to develop control strategies to integrate numerous vehicles with distributed energy resources at numerous facilities
- Focus on electrical interactions and system dynamics
- Trial multiple communications pathways to accelerate standards development

Accomplishments

- Use cases and communication pathways to be emulated identified and down-selected
- Development of HIL environment underway
  - Smart Energy Box procurement
  - Vehicle charging system integration with DRTS

Partnerships

- 5 national labs
- Siemens
- Advisory Board
- Project being coordinated with other GMLC efforts
  - GM0086 –*Modeling and Control Software to Support V2G Integration*
  - GM0062 – *Vehicle to Building Integration Pathways*
  - GMLC foundational projects

Reviewer Only Slides

Publications and Presentations

No presentations or publications yet – project was recently started

Critical Assumptions and Issues

- Use cases will be initially selected based on literature reviews, engineering judgement, and Advisory Board feedback. This project will structure model requirements and initial evaluations (early FY17) around those use cases. If GM0086 identifies different use cases that have higher value, based on market-level analysis, this project will adjust to include evaluation of system dynamics and controls of those use cases.
- HIL environments at INL and NREL will be connected via the existing VPN connection between INL/NREL DRTS systems. This will allow actual DER hardware at NREL's Energy Systems Integration Facility to be included in FY17/18 evaluations.
- Control agents will be implemented using PNNL's VOLLTRON software. GM0062 may use a different approach for agent-based control. If this is the case, the method for integrating communication hardware from GM0062 in FY17/18 will need to be reevaluated.