# *Grid Modernization Laboratory Consortium: Systems Research for Standards and Interoperability (GM0085)*

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elt194

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Idaho National Laboratory

# Overview

## Timeline

- Project start: April 1, 2016
- Project end: April 30, 2019
- Percent complete: 60%

## 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

## 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

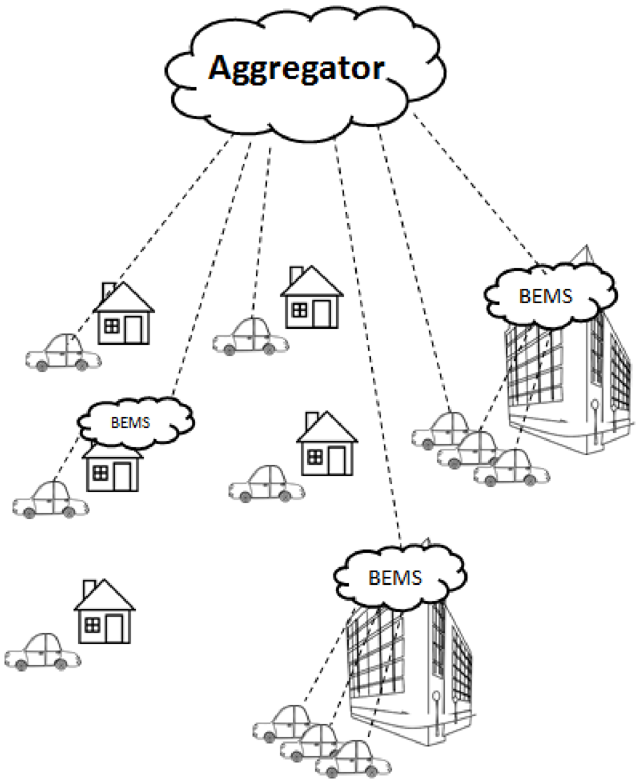
# *Project Objectives/Relevance*

- Determine the feasibility of PEVs providing grid services via an aggregator at the electric utility distribution level
- Develop a methodology for controlling PEV charging
- Quantify the benefits of controlling PEV charging
  - Cost savings of avoided distribution feeder upgrades
  - New generation capacity avoided

- Relevance to Barriers
  - Develop and validate a control strategy to integrate the **infrastructure** and **avoid risks** of negative grid impacts

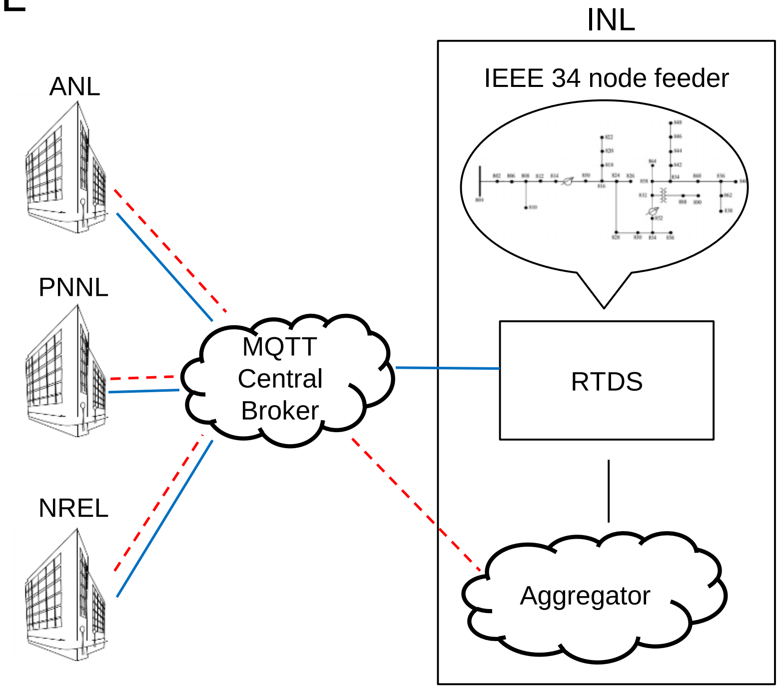
# *Approach*

- Develop an aggregator that can be used to coordinate charging of PEVs to provide grid services
  - Coordinate with buildings
  - Coordinate with PEVs directly
- Use aggregator platform to study effectiveness of aggregator to provide benefit to the grid
- Study PEV charging in two contexts:
  - Charging at commercial buildings
  - Charging at residences



# Approach: Charging at Commercial Buildings

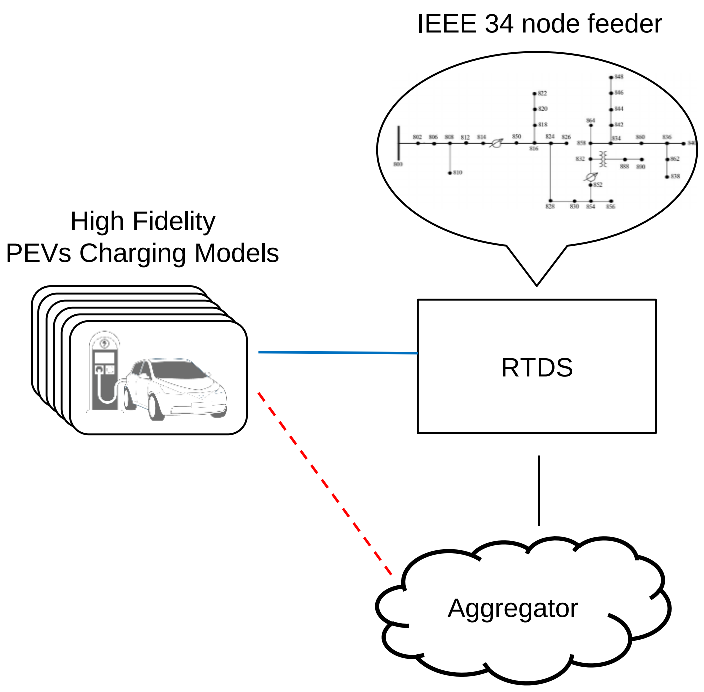
- Working closely with "Vehicle to Building Integration Pathway" (GM0062)
- As part of the GM0062 project, the hardware, communication, and controls needed to integrate PEV charging into buildings has been implemented in buildings located at ANL, PNNL, and NREL
- These buildings will interact with real-time digital simulator (RTDS) and aggregator located at INL
- Each building directly controls the PEV charging of all PEVs located at the building
- The aggregator communicates with the buildings and coordinates their response across the distribution feeder




*This platform will study the ability of PEVs charging at commercial buildings to provide grid services*

# Approach: Charging at Residences

- The charging of 10,000's of PEVs on the IEEE 34 node feeder will be simulated using an RTDS
- High-fidelity PEV charging models will interact with the RTDS simulation
- These PEV charging models will be validated against lab test data
- The non-PEV feeder load will be based on typical PG&E residential load




*This platform will study the ability of PEVs charging at residences to provide grid services*

# *Approach: Quantify Benefit of Controlling PEV Charging*

- After the simulations have been run, the economic benefits of controlling PEV charging will be quantified
- The costs savings of distribution feeder upgrades avoided will be calculated based on the IEEE 34 node feeder used in simulation
- The new generation capacity avoided will be calculated for the PG&E utility footprint

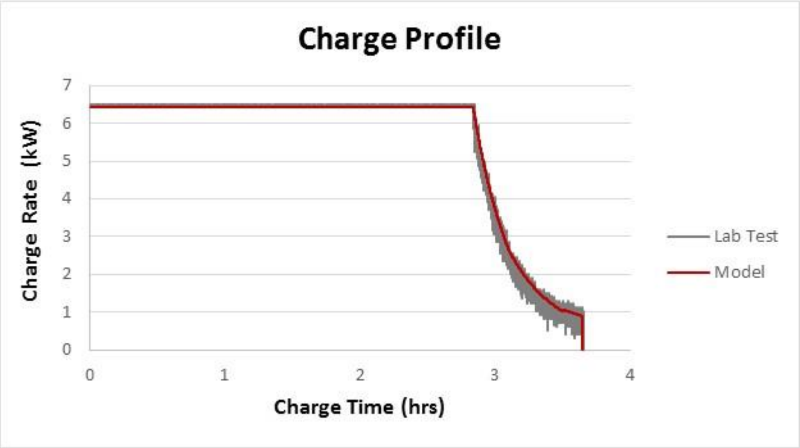
# FY17/18 Milestones

| Milestone Name/Description | End Date |
|---|---|
| Complete a baseline demonstration of uncontrolled charging using the DRTS with simulated distribution network, PEV charging system characterization models, and simple PEV state models | Complete |
| Complete VGI study of at least 3 use cases, in which PEV charging is controlled to provide grid services | Complete |
| Develop and test forecast and building load data communication messages between ANL, INL, PNNL, and NREL | 6/30/2018 |
| Demonstrate capability of the aggregator to communicate and integrate with the building control developed in GM0062 | 10/31/2018 |
| Demonstrate capability of building control at ANL, PNNL, and NREL to stay below the upper energy limit provided by INL. Verify feedback from the buildings can be integrated into the real-time simulation | 10/31/2018 |

# Accomplishments: Charging at Residences

## Characterize PEVs
## Create high-fidelity charging models

- Characterized the behavior of production PEVs as loads on the grid
- Used this data to create high fidelity charging models for the: 2015 Leaf, 2016 Volt, 2013 Fusion
- Charging models were validated by comparing model output to lab tests
- Using charging models can investigate the impact of 100's of thousands of PEVs charging on a distribution feeder

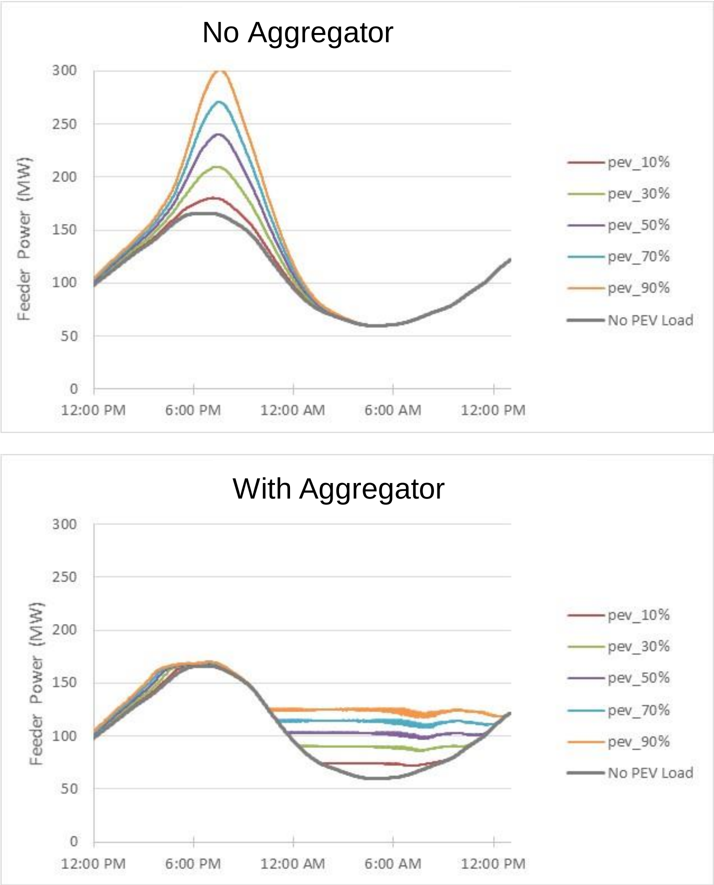




*Comparison of lab test with model output for 2015 Leaf*

# Accomplishments: Charging at Residences

## Develop an aggregator that can coordinate with PEVs directly

- Uses a two-step optimization
  - The first step optimizes the total PEV charging energy for the next 15 minutes.
  - The second step allocates the total charging energy to the PEVs based on charging need.
- Has the following benefits:
  - Ensures maximum charging efficiency and power quality
  - Ensure PEV charging needs are met
  - Not sensitive to internet latency
  - Scalable and computationally efficient
    - Solution consistently found in 10-15 seconds on a desktop pc for 1,000,000 PEVs.

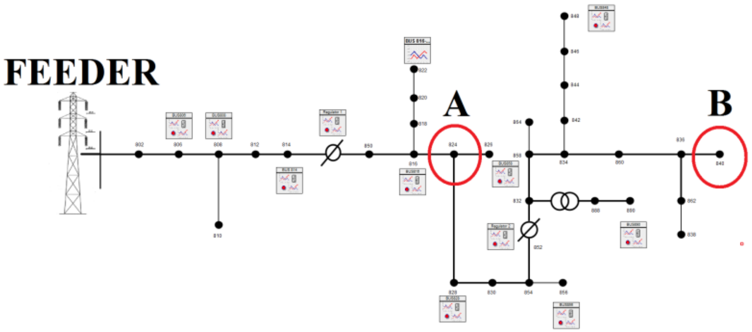



*Feeder demand (MW) with and without an Aggregator for the following PEV penetrations (10%, 30%, 50%, 70%, 90%). The feeder consisted of 100,000 homes in the PG&E service territory.*

# Accomplishments: Charging at Residences

## Scenario: 50% PEV Penetration

- Ran a simulation on RTDS using high-fidelity PEV charging models
- System Composition
  - 75,000 Homes
  - 50% of homes own PEV
  - IEEE 34 node test feeder
- Non PEV feeder load
  - 2016 typical residential PG&E load data
  - Downloaded from PG&E website
  - The day in 2016 with the highest peak load used

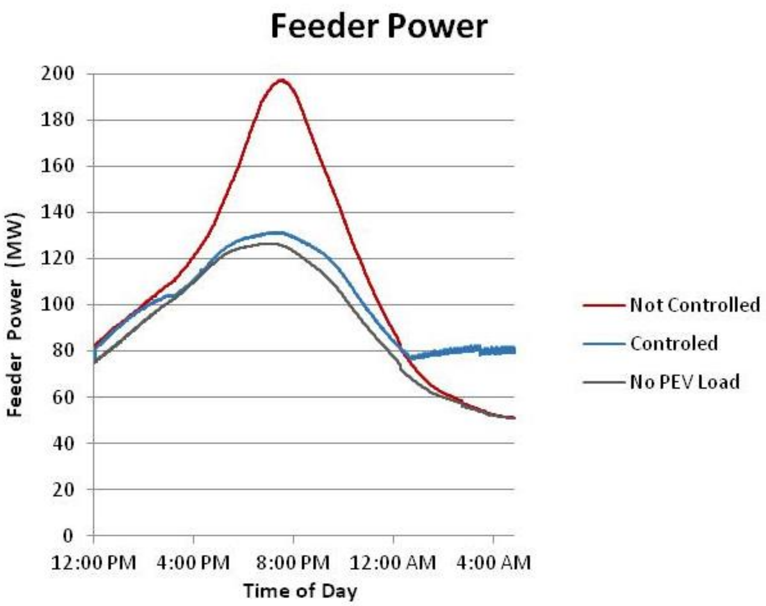



Source: INL

# Accomplishments: Charging at Residences

**Scenario: 50% PEV Penetration**
**Grid Service: Capacity Deferral**

- PEVs provide capacity deferral when charging is coordinated with an aggregator
  - 65 MW of capacity deferred in this example
- Uncontrolled Charging
  - Aligns the PEV peak with the non PEV peak load
  - Increases the ramping and variation in load shape
- Controlled Charging
  - Shifts PEV charging to off peak hours
  - Flattens the load shape mitigating the need for capacity upgrades




*Feeder Peak:*

*127 MW -> No PEV Charging*

*132 MW -> Controlled PEV Charging*

*197 MW -> Uncontrolled PEV Charging*

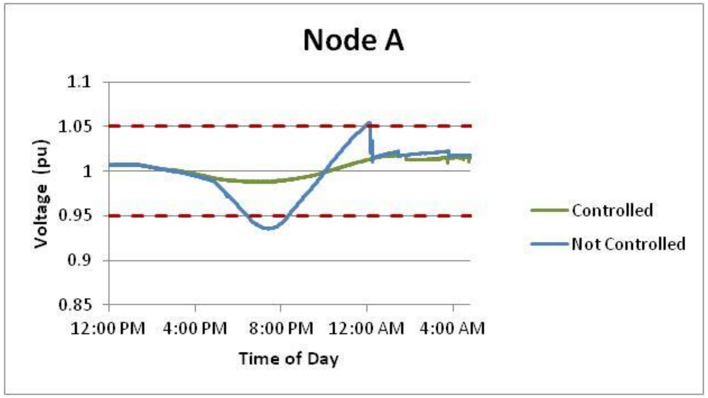
*Controlled Charging requires 4% increase in capacity*

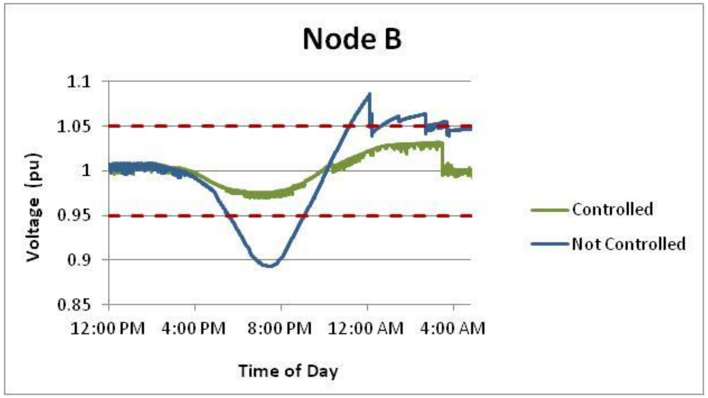
*Uncontrolled Charging requires 55% increase in capacity*

# Accomplishments: Charging at Residences

**Scenario: 50% PEV Penetration**
**Grid Service: Voltage Support**

- PEVs provide voltage support when charging is coordinated with an aggregator
- Voltage profile is flatter when PEV charging is controlled
- Uncontrolled Charging
  - Voltage deviates outside normally accepted limits (+/- 5% of nominal)
  - This requires utility upgrades to address the issue
- Controlled Charging
  - Voltage is within normally accepted limits (+/- 5% of nominal)
  - No utility upgrades needed

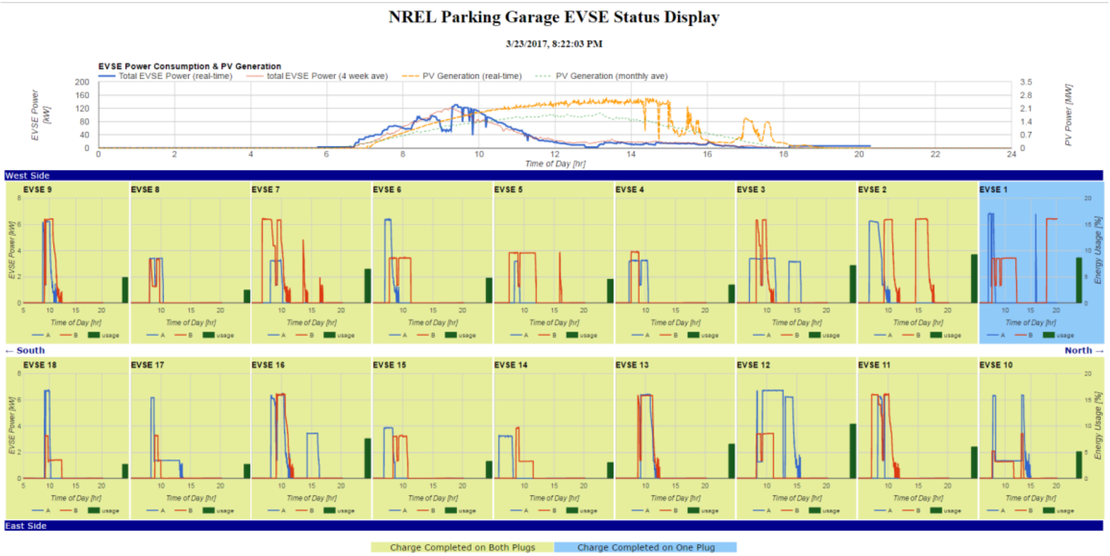



*Node A is closer to the feeder substation than Node B causing Node A to have less variation in the voltage profile than Node B.*

# Accomplishments: Charging at Commercial Buildings

- As part of the GM0062 project, the hardware, communication, and controls needed to integrate PEV charging into buildings has been implemented in buildings located at ANL, PNNL, and NREL
- This development is a key building block needed to study the feasibility of PEVs charging at commercial buildings to provide grid services




*PEVs at the NREL parking garage responding to a demand response event*

# *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**: communication research; develop and host central broker to link GM0085 and GM0062
  - **LBNL**: aggregator-level control requirements; quantify the saved cost of distribution feeder upgrades not needed when PEV charging is controlled
  - **NREL**: development of PEV charging aggregators; evaluation of controlled PEV charging
  - **PNNL**: aggregator-level control requirements; control agent selection and integration
- **Siemens:** provide Siemens Smart Energy Box and support development of controls interface between DRTS, front-end controller, and aggregator models
- **Advisory Board**: review use cases and communication pathway selection; review interim and final results of control strategy

# *Remaining Challenges and Barriers*

- There is no standard definition of an EV aggregator or standard practice for coordinating EV charging beyond the building level
- Research is required to understand how to coordinate building load control to meet the needs of the broader grid without negatively impacting buildings (e.g. incurring demand charges)
- The value proposition for aggregation and charging control has yet to be determined

# *Proposed Future Work*

- Develop an aggregator to communicate with buildings and coordinate their response across a distribution feeder to achieve a grid objective or provide a grid service
- Develop communications platform to exchange information between the aggregator and distribution feeder simulation located at INL, and building control systems located at ANL, PNNL, and NREL
- Use hardware-in-the-loop platform to study the ability of PEVs charging at commercial buildings to provide grid services
- Quantify the benefits of controlling PEV charging using the following two metrics:
  - Avoided cost of distribution feeder upgrades when charging is controlled
  - New generation capacity avoided when charging is controlled

# Response to Previous Year Reviewers Comments

Comment 1: “Emulating communications using hardware in the loop and performing dynamic real-time simulations seems like the best way to model these complex system interactions and help predict how integration of PEVs with the grid may take place.”

Response: The chosen approach is effective to study the complex electrical interactions between EVs and the grid; we have taken a depth-over-breadth approach.

Comment 2: “This is a highly collaborative project…. It would be good to understand more about how decisions are going to be made.

Response: Because of the number of partners, alignment of tasks has been challenging. The project team recently completed a formal project review and update tasks to ensure successful completion.

Comment 3: “The project is also linked to other laboratory projects, and thus it is important to align timelines.”

Response: The first phase of the project, aggregator development for direct control of vehicles in residential settings, was conducted in parallel with GM0062 building controller development. Work on integrating the aggregator with buildings has begun in earnest, with GM0085 and GM0062 now working in tandem.

# Summary

## Relevance

- Determine the feasibility of PEVs providing grid services via an aggregator at the electric utility distribution level
- Develop a methodology for controlling PEV charging
- Quantify the benefits of controlling PEV charging

## Accomplishments

- Completed high-fidelity PEV charging models and integration into RTDS
- Developed an aggregator control strategy and completed study of direct control with high PEV penetration
- Demonstrated 41% reduction in peak demand and successful voltage support through aggregator control
- Completed plan for integration of aggregator with building-level control strategy in GM0062

## Approach

- Develop an aggregator that can be used to coordinate charging of PEVs to provide grid services
- Use aggregator platform to study effectiveness of aggregator to provide benefit to the grid in two contexts:
  - Charging at commercial buildings
  - Charging at residences

## Partnerships

- 5 national labs
- Siemens
- Advisory Board
- Project being coordinated with GM0062 – Vehicle to Building Integration Pathways