EV Project - Solar-Assisted Charging Demo

Principal Investigator: Melissa Lapsa


June 16-20, 2014
Overview

Timeline
- Start date August 2009
- End date September 2014
- 80% complete

Barriers
- Integrating multiple technologies
- Securing site hosts
- Market acceptance of EVs
- Securing cost-share partners

Budget
- Total project funding
  - DOE share $6.8 million
  - Matching partners’ share $6.8 million
- Yearly spending:
  - FY10 $514,000
  - FY11 $1,661,000
  - FY12 $2,777,000
  - FY13 $1,283,000
  - FY14 $280,000 (through March)

Partners
- Project lead – ORNL
- Project partners – TVA, Nissan, EPRI, State of Tennessee, and eight site hosts across Tennessee
Objectives

• Advance the adoption of clean vehicle technology (plug-in vehicles) through:
  - The deployment of 125 solar-assisted EV charging stations and 19 non-solar-assisted EV charging stations
  - Encouraging the acquisition and use of plug-in vehicles
  - Creating key partnerships across Tennessee

• Integrate renewable energy, vehicle charging, grid connection, and external battery storage into a single design

• Develop and test peak-shaving algorithms for offsetting plug-in vehicle grid demand

• Collect and analyze vehicle charging data for understanding grid impacts and station use patterns
Approach – Design Components
Approach – Nissan Installation
Approach – ORNL Non-Solar and Knoxville Solar Installations

- ORNL West End Campus
- National Transportation Research Center (NTRC II)
- Knoxville Civic Coliseum

OAK RIDGE National Laboratory
Approach – Other Installations

ORNL Solar Assisted

Vanderbilt University
Technical Approach

• Design stations with independent grid-connected elements of solar power, EVSEs, and external batteries
• Design solar power installation to offset grid demand at all times when solar power is being produced
• Include grid connection so drivers can charge vehicles without dependence on solar production (night and cloud-covered days)
• Connect external battery to the grid to offset grid demand at selected times
• Install sufficient solar capacity to support 10,000 miles of EV driving per year, per vehicle parking space, on renewable power
Technical Approach - Continued

- Use commercially-available, UL-listed components given public use of the stations
- Develop real-time website to display cars charging, solar production, state of external battery, and ‘net solar vs. demand’ for project to date
- Collect and analyze data on charging station utilization and energy use (consistent with requirements of the DOE grant)
- Develop an ongoing statewide team for review of data and for making strategic choices (TEVAC – Tennessee Electric Vehicle Advisory Council)
Technical Approach - General System Diagram

\[ P_{NET} = (P_{EVSE}) - (P_{PV}) + (\pm P_{BB}) \]
Technical Accomplishments and Progress

- Installed 144 fully-functional EV charging stations
- Cost-share partners made the agreed-to investments and installed the agreed-to infrastructure
- Successfully integrated the power grid, solar power, EVSE, and external batteries into a single design
- Developed a real-time website for monitoring the solar-assisted station at ORNL
  https://extwebapps.ornl.gov/pvev_ext
- Tested, selected, and deployed a peak-shaving algorithm to optimize use of the external battery
- Converted raw data into user-friendly energy consumption and station utilization charts
- Embarked on the creation of an I-40 corridor EV charging route across Tennessee
Station Utilization – ORNL Overall

Station Utilization – ORNL Non-Solar-Assisted
Station Utilization – ORNL Solar-Assisted

Total Number of Charges Each Quarter

% Utilization for 2013Q4: 23.7%

Average Number of Charge Events by Day of Week
Comparison of ORNL Campus and Public Setting – Energy Consumption

**ORNL (Quarter 3, 2013)**

- Energy consumption per charge:
  - Min: 0.00
  - Max: 22.17
  - Avg: 8.55

- Additional miles available from each charge event:
  - Min: 0.00
  - Max: 63.41
  - Avg: 24.45

**Nashville State (Quarter 3, 2013)**

- Energy consumption per charge:
  - Min: 0.36
  - Max: 20.81
  - Avg: 9.10

- Additional miles available from each charge event:
  - Min: 1.03
  - Max: 59.52
  - Avg: 26.04
Comparison of ORNL Campus and Public Settings: Charging Times

**ORNL (Quarter 3, 2013)**

- **Connection Times**
  - Min: 2:32 AM
  - Max: 9:17 PM
  - Avg: 9:37 AM

- **Disconnect Times**
  - Min: 12:13 AM
  - Max: 11:44 PM
  - Avg: 3:24 PM

**Nashville State (Quarter 3, 2013)**

- **Connection Times**
  - Min: 1:30 AM
  - Max: 11:40 PM
  - Avg: 1:21 PM

- **Disconnect Times**
  - Min: 12:21 AM
  - Max: 11:51 PM
  - Avg: 4:39 PM
## Technical Accomplishments and Progress - Peak Shaving Algorithms

### Increasing Complexity

<table>
<thead>
<tr>
<th>Control System #1</th>
<th>Control System #2</th>
<th>Control System #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-loop system</td>
<td>Closed-loop system</td>
<td>Similar to control system #2</td>
</tr>
<tr>
<td>discharge/charge batteries at constant rate</td>
<td>Takes into consideration PV power and EV charging load</td>
<td>Uses a sigmoid function to determine the rate of discharge</td>
</tr>
<tr>
<td>Defined times to start and stop discharging</td>
<td>Rate of discharge determined by number of charging EVs (linear function)</td>
<td>Charging occurs at night and times during the day where PV generation is greater than EV charging load</td>
</tr>
<tr>
<td>Does not take PV power and EV charging load into consideration</td>
<td>Charging occurs during the night time</td>
<td></td>
</tr>
<tr>
<td>Charging occurs during the night time</td>
<td></td>
<td></td>
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</tbody>
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Technical Accomplishments and Progress - Peak Shaving Algorithms

- The most shaving occurred for control systems #2 and #3.
- Control #2 has slightly better results for a workplace setting.
- Control #3 has the best results for a public setting.

<table>
<thead>
<tr>
<th>Control System</th>
<th>ORNL</th>
<th>Knoxville</th>
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<tbody>
<tr>
<td>1</td>
<td>33.99%</td>
<td>0.37%</td>
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<tr>
<td>2</td>
<td>60.61%</td>
<td>74.74%</td>
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<tr>
<td>3</td>
<td>59.03%</td>
<td>76.62%</td>
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</table>

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</thead>
<tbody>
<tr>
<td>1</td>
<td>17.97%</td>
<td>0.17%</td>
</tr>
<tr>
<td>2</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>3</td>
<td>100%</td>
<td>100%</td>
</tr>
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Collaborations/Partnerships

- **Nissan North America** – Installed 30 solar-assisted charging stations at a cost of more than $1.7 million
- **Tennessee Valley Authority with EPRI** – Installed 36 solar-assisted charging stations at a cost of more than $2.75 million
- **State of Tennessee** – Provided vehicle incentives in excess of $1.8 million and infrastructure commitment of $2.5 million
- **Eight site hosts** including the State of Tennessee, Nashville Metro Government, University of Tennessee, Vanderbilt University, City of Knoxville, City of Chattanooga, Shelby County in Memphis, and Tennessee Valley Authority (TVA)
**Future Work**

- Potential partnership (CRADA) with Car Charging to continue analyzing data in Tennessee to:
  - Improve utilization of all Blink stations across Tennessee
  - Enhance DOE’s ‘return on investment’ by growing the use of the stations
  - Enable improved planning for future infrastructure
  - Continue grid impact/peak shaving analysis to better understand ways to mitigate EV charging impacts to the grid

- **Complete the State of Tennessee funded project for additional infrastructure**
  - Interstate 40 corridor for fast charging stations
  - Additional Level 2 charging
  - Selected metro sites for fast chargers

- **Implement post-project plan for employee use of stations at ORNL**

- **Continue with the Tennessee Electric Vehicle Advisory Council**
DC Fast Chargers in Tennessee: Expanding the infrastructure

Original map overlays by Ecotality

- Existing
- Potential future sites
Objectives Have Been Met
- Planned charging stations are installed and functioning
- Cost share dollars have been spent or are being spent
- Peak shaving algorithm has been developed and deployed
- Key partnerships are in place across Tennessee
- Data is being collected, summarized, and used
- The final report is in preparation and will be submitted by 9/30/14
- Stayed within budget and met all deliverables

Future actions offer excellent potential

Project was not reviewed last year