EV V2G School Bus
Demonstration Projects

Findings & Background on EV V2G School Bus Demonstration Programs
Roadmap 12
6/18/19
• Acknowledgement of Partners
• Background on Approach
• Findings from Phase 1 Demonstration
• Update on Phase 2 Demonstration
• Questions
Phase 2 EV V2G School Bus – DoE/Blue Bird Demonstration Project
Why School Buses?

- Very predictable daily operations
- National Average is 80 miles per day
- 4-8 average hours per day in operation
- Most buses run the same route every day
- Fleet size typically runs 10-100 per school district, but as large as 1,500
- Generally park in two locations – Depot and/or school building
- Significant non-operational time – nights, weekends, holidays, summer
- School buses are generally owned, operated or contracted by the public sector
- School buses are large – lots of room for batteries and it is energy storage that drives V2G revenue. Under current design configuration 10-15 EV V2G school buses will represent over 1 MW of energy storage/delivery.
Why V2G?

- Project started with this question: “If Frito Lay can deliver potato chips in a zero emissions van, why can’t we do the same with our children to schools in school buses?”
- Clinton Global Initiative took on this challenge
- The premise was how to reach TCO parity between ZEV school buses and fossil fuel versions
- Modeling indicated operational and maintenance savings would not achieve TCO Parity
- The question became could V2G tip the balance
- Early data models indicated that V2G revenue can range from $5,000 to $20,000 per bus per year.
Phase 1 – Proof of Concept

• NSI awarded grants from California Energy Commission and South Coast AQMD of $3.8M
• Project team assembled ranging from school bus drivers to CAISO
• Funding to retrofit six school buses with ZEV V2G system with interconnection agreement funding with one IOU (SCE)
• All buses met operational requirements for pupil transportation
• Battery information:
  • 300 ampere-hour (Ah) lithium iron phosphate (LiFePO4) cells manufactured by Winston, a Chinese battery manufacturer, and distributed in the U.S. by Voltronix
  • 120 cells in the entire subsystem, which provides a total of approximately 115 kilowatt-hours (kWh) of total energy storage
Phase 1 – Proof of Concept

- Two of six buses deployed to Torrance USD for V2G demonstration with 70kwh bi-directional inverter
- Behind-the-Meter Interconnection agreement negotiated with SCE (First V2G school bus agreement in the world)
- Two buses were connected to TUSD subpanel to reduce demand charges/power usage related to CNG filling station for school bus fleet
- Initial data indicated school buses reduced net energy charge by $5,000 per bus per year
- TCO to School Bus Parity was in reach
Phase 1 – Proof of Concept
Phase 1 – Proof of Concept
Phase 1 – Proof of Concept
Phase 2 EV V2G School Bus – DoE/Blue Bird

- Creation of a $10M Demonstration Project with Purpose Built New ZEV V2G School Buses
- Blue Bird Awarded a $4.9M Grant from U.S. DoE ($400k to NREL) in December 2016
- Additional $1.9M from South Coast Air Quality Management District; plus additional resources developing from CA based IOUs and other entities and matching resources from participating partners.
Phase 2 EV V2G School Bus – DoE/Blue Bird Overview

- Project Elements:
  - Up to a 155kwh battery (Li-NMC-G); 150kwh bi-directional inverter (UL/IEEE certification)
  - 120 Mile Range
  - Energy Efficiency Target: 1.1kwh/mile
  - Eight Production Buses for Demonstration at Rialto USD (CA)
  - Charging Infrastructure Development and Installation
  - V2B/Emergency Power also to be demonstrated
  - Additional Demonstration sites being sought
V2G – What are the economic possibilities?

• At TUSD the results were positive - $5,000 net energy cost reduction per bus per year
• Modeling for RUSD program - ~$6,000 net energy revenue per bus per year from CAISO market participation
• Financial value of V2G to vehicle owner/operator is still uncertain
  • Utility/ISO territory impact value
  • Value will change positively/negatively over time
  • Behind the meter has real benefits in our TCO models
V2G – What are the technical challenges?

• The Technology – both hardware and software exist today and improvements are always occurring
• Certifications – UL v. ASE – the debate continues and no clear answer (see policy).
V2G – What are the policy challenges?

- As noted previously – certification of invertors, both on-board and off-board, particularly AC On-Board remain an issue.
- Some state PUCs (particularly CPUC through Rule 21) are exploring this issue in an attempt to resolve it.
- Phase 2 is a part of SCE’s EPIC AC On-board research program.
- Also due to policy uncertainty on various energy markets we are not able to currently determine costs and revenues of V2G.
V2G – What is our stakeholder engagement model?

• Beyond six contributing members of project team (e.g. prime and subcontractors) – it is necessary to stay in regular touch.

• These stakeholders include:
  • Utility/ISO
  • Public Sector/Regulators
  • Vehicle Operators
Findings & Lessons Learned

• Early Stage V2G is not for the faint of heart
• Now that OEMs are manufacturing the “V” in V2G more success will be achieved
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• Project tied into Rialto USD’s construction of a new pupil transportation facility
• $300-$400K incremental cost to provide high-power charging system for eight buses
• Worst case within best-case scenario
Charging System: Connector

- SAE J3068 compliant
- 120A per connector
- Two connectors per bus to support 180A (150 kW) total charge/discharge capacity
Charging System: Connector

SAE J3068 Touch Resistant on Both Sides

CHALLENGE – During V2G operation high power and high voltage can be present on either side of the connector
Charging System: EVSE

- Nuvve PowerPort
- Serves as communications node between charging controller and on-board inverter
- 480V 3Ф in and out
- Current power capacity 120A; next generation will likely have 180A capacity
- “Thin and affordable”
Charging System: Inverter

- EPC Power Corp. MG Module
- 150 kW power capacity
- Fully bidirectional (charge/discharge)
- Currently being optimized for on-bus deployment
- Grid-tie and off-grid operation
- Already certified to most provisions of UL1741
- Will undergo UL1741 SA testing 3Q19
AC vs. DC High-Power Charging

- Not clear which approach will prevail

Pros for DC Charging
- Allows motor companies and charging appliance companies to divide and conquer
- No UL1741 certification ambiguity

Pros for AC Charging
- Potential for vehicle-level cost advantage
- Will lead to lowest system cost
Charging System: V2G Control Platform

- Determination of when and at what rate to charge or discharge will be made by Nuvve’s Energy Regulation Aggregator.
- The Aggregator will be programmed with rules and instructions; monitor state-of-charge; and act on real-time grid signals to provide ancillary services.
- Participation in ancillary service markets will be facilitated by a third-party scheduling coordinator.
Interconnection

• Will submit an application to Southern California Edison for interconnection under CAISO’s Wholesale Distribution Access Tariff
• Want the option to participate in wholesale power markets
• Essential terms and conditions of relationship with SCE will be negotiated after interconnection application approved
• T&C’s must be in place to determine highest-value uses of the resource