BorgWarner

Pioneering Commercial Vehicle-To-Grid In Electric School Buses

March
2023

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Results From Two Seasons Of V2G Participation

Summary panel

In the summers of 2021 & 2022, Highland Electric Fleets & BorgWarner used vehicle-to-grid (V2G) technology to discharge 10+ MWh hours to the Massachusetts grid over 158 hours -- the first time battery storage from electric school buses (ESBs) was used in a commercial V2G program in the United States. Participation generated $23k in revenue and demonstrates the value ESBs can deliver to support the grid and lower the cost of ownership of an electric bus fleet.

Challenges Facing The Electric Grid

Extreme weather and increasing peak loads are challenging the electric grid's resilience and ability to deliver reliable electricity across North America. Recent events such as Hurricane Ida, the Texas cold snaps in 2021 & 2023, and

the extreme heatwave of 2022 underline the need for backup power storage. Power outages during these events revealed the vulnerability of power systems that keep essential services such as schools, nursing homes, and healthcare facilities online. In addition, increasingly extreme temperatures cause spikes in demand, which necessitate firing up inefficient & carbon-intensive fossil fuel peaker plants. As the grid evolves and a growing number of services and products become electrified, electric grids around North America will require novel solutions to remain reliable and resilient. The potential power available from expanding electric vehicle (EV) fleets can help manage disruptions as they unfold and mitigate the impact of power outages or demand spikes on communities.

What Is V2G?

Vehicle-to-grid (V2G) technology allows an EV to both draw energy from the grid (typically during periods of low cost and low demand) and discharge energy back to the grid (during periods of higher cost and high demand). Highland Electric Fleets (Highland) -- in partnership with BorgWarner, Thomas Built Buses, Proterra, and Synop -- is pioneering commercial V2G technology for electric school buses (ESBs), which supports grid stability and reduces the cost of fleet electrification for school districts & fleet operators.

How Can EVs Support The Grid?

V2G transforms EVs, such as electric school buses (ESBs), into mobile batteries that can be used to help stabilize the electric grid. This class of Distributed Energy Resources (DERs) is pivotal to the evolution of the electric grid. Increasing amounts of variable renewable energy can cause fluctuations on the electric grid: energy storage, including from batteries in ESBs and other EVs, plays a critical role in balancing and buffering the intermittency of resources like wind and solar. In addition, utilities can reduce emissions by using electric school buses as DERs when energy demand spikes, rather than firing up conventional fossil fuel resources for short periods of time.

Reducing The Cost Of Electric Fleet Ownership

Aside from helping stabilize grids with intermittent renewable energy generation and reducing emissions, V2G technology also helps reduce energy costs associated with owning and operating EV fleets. Bi-directional charging infrastructure typically costs more than "standard" unidirectional chargers, as do licensing costs for the aggregator software. The Return On Investment (ROI) on these chargers varies but is typically shortest for bigger vehicles with larger battery packs that are parked for a large percentage of the day. School buses, in particular, have the potential for the shortest ROI due to both their battery capacity and the extended time that they are in the vehicle yard, especially given their presence during most peak demand hours.

In addition, an increasing number of electric utilities, like National Grid, support programs that pay electric fleets and other battery storage resources to discharge energy, turning them into revenue-generating assets without disrupting normal operations. Highland uses private sector financing mechanisms, bus purchasing power, expertise in project design and implementation, and management of electricity costs (including V2G) to make fleet electrification easier & less expensive for school districts & municipal entities. Highland works with partner fleet operators to pass through V2G revenue to customers to reduce the overall cost of fleet electrification.

V2G Participation Data

In the summers of 2021 & 2022, Highland & BorgWarner piloted V2G technology using battery storage from electric school buses. The buses discharged 10+ MWh hours to National Grid over 158 hours from an ESB depot in Beverly, Massachusetts.

	Data
Summer Periods (One bus)	2
Participation Days	70
Participation Hours	158
MWh to Grid	10.78
V2G Revenue	$23,500

Tech & Implementation

Hardware

Vehicle & battery specifications

Saf-T-Liner® C2 Jouley™ electric bus by Thomas Built Bus & Proterra

Total Energy (Kwh)	220
Motor	Proterra ProDrive drivetrain; single 220kW permanent magnet drive motor
Operating Efficiency	kWh/mile - 1.4
MPGe	24.6
Range	Up to 135 – Operating range in miles usable energy/efficiency
Top Speed	65 mph
Horsepower	295 peak, 170 continuous
Braking System	Regenerative braking, air disc brakes

Charger Specifications

Bidirectional DC Fast Charging System By BorgWarner

The modular DC fast charging system (DCFCS) from BorgWarner consisted of a RES-DCVC-60-V2G Power Conversion System (PCS) and a RES-D2-CS20 power dispenser. The PCS unit was installed near the 380 VAC 3-phase power input next to the building and the dispenser unit near the buses in the parking lot. The modular design allowed Highland to install the dispenser up to 500 feet from the PCS unit. By separating the PCS from the dispenser, the DCFC is well-designed for fleet applications where there is limited space. Both units are environmentally rated to NEMA 3R and handled continuous operations outdoors throughout the two summers during this case study. The bidirectional system delivered up to 60kW of continuous rated DC power with an output range of 270Vdc to 870Vdc to the electric bus throughout the events. Optional 125kW bidirectional DCFC are also available for larger battery system vehicles.

The PCS and dispenser units are certified to UL-1741-SA and incorporate galvanic isolation to meet the utility's requirements for putting power back into the grid. Highland and BorgWarner used Open Charge Point Protocol (OCPP) as the application protocol to communicate between Highland's energy operator and the charging station, control when the bus should charge, and provide power to the grid. To initiate a discharge event, the utility communicated the energy discharge requirements, which Highland then dispatched to the charging station

Software

Vehicle & Charge Management Software - Synop

Highland uses Synop as the vehicle and charge management platform powering Highland Dashboard. This software integrates with key ecosystem components (vehicle, charger, and utility) that enable V2G transactions. V2G events were triggered manually in the 2021 season and via the platform in 2022. The platform receives prompts from National Grid for a specified time period, then validates the vehicles' fleet charging schedule to ensure excess capacity. Once validated, the Synop platform delivers the appropriate charging schedule to the chargers via the OCPP, and energy is discharged from the battery back to the grid. Highland & Synop monitor this discharge in real time and generate reports to validate the V2G event.

About BorgWarner

For more than 130 years, BorgWarner has been a transformative global product leader bringing successful mobility innovation to market. Today, we're accelerating the world's transition to eMobility — to help build a cleaner, healthier, safer future for all.

About Highland Electric Fleets

Highland Electric Fleets is the leading provider of fleet electrification-as-a-service for municipal and government fleets in North America. Active in 30 states and Canada, Highland is responsible for the largest electric school bus deployment in the United States.

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