

High voltage utility connected Level 2 Electric Vehicle charging

Natural Resources Canada Energy Innovation Program—Electric
Vehicle Infrastructure Demonstration

Public Report For EVID–084 Project

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Photo credit: City of Abbotsford, courtesy of SMPC Technologies

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Summary

The High Voltage–Utility Connected (HVUC) L2 charger demonstration project supports market transformation towards the use of clean electricity for the transportation sector by eliminating key barriers to electric vehicle (EV) adoption in urban centers. An innovative EV charger design was proposed with a unique high voltage input, integrated power transformation topology, and a utility meter. The HVUC charger project has completed the design, fabrication, assembly and commissioning of the Level 2 chargers. Safety certification and compliance tests on the chargers are complete. All 60 chargers were produced, and were later installed at customer sites, where installation costs were reduced, mainly because the usual transformer and associated wiring weren't required. The project has spawned a wealth of new knowledge and development opportunities identified for the local manufacturer of the chargers, along with benefits to customers, utilities, installers and engineering firms.

While the deployment phase of the project is complete, the project team will continue to study the benefits of the chargers and their impact in promoting wider EV adoption.

Background

Driver range anxiety remains among the key barriers to plug-in electric vehicle adoption, and governments have recognized the need for a critical network of public charging infrastructure to help erode concern around how and where to charge. In B.C., the charging network has been growing with the help of provincial and federal government initiatives that have helped make it easier for EV drivers to charge their vehicles within cities and small communities, and to charge quickly and conveniently along major highway corridors.

As the level of EV adoption increases, the infrastructure challenge shifts to ensuring that the bulk of charging occurs where it's most convenient: in private residences and within commercial buildings. Many residents in urban centres live in multi-unit residential buildings (MURBs) and there's an increasing expectation that commercial building operators provide charging options for tenants, car share and employees. These factors demand a solution that can enable:

- Energy disaggregation by EV user.
- Development of EV-specific utility programs and tariffs.
- Reduction of electrical losses and the cost of charging infrastructure installations.

The High Voltage Utility Connected project was designed to advance these goals.

More than 70% of residents in Metro Vancouver now live in multi-unit residential buildings. Challenges facing potential EV owners in apartments and townhomes include both charger installation costs, which may require upgrades to shared facilities, and disaggregation of personal energy use from the common building. Both challenges represent significant barriers to EV adoption, since most owners do the majority of their charging at home and it's considered a highly desirable convenience.

The challenge

Current level 2 (L2) EV chargers (7–10kW) use low voltage AC (240 VAC) as an input. In commercial buildings and MURBs, installation of chargers typically requires a low voltage service upgrade and distribution to designated parking stalls. And that service upgrade typically requires the addition of a designated transformer to convert facility voltage (typically 347/600 VAC) to the required low voltage (208/240 VAC). The additional transformer is costly, it's often oversized to accommodate worst-case peak loads, and costly expansion of designated charging circuits may be required in the future. The presence of this large transformer also produces significant standby loads when not in use or only partially loaded, and degrades the facilities power factor due to the presence of the large inductance.

The result is additional cost penalties from utilities, which hit utility customers in the pocketbook. Poor power factor for a 75kVA transformer (required for installation of 10 level 2 stations) can cost a BC Hydro customer between \$60 and \$160 per month.

The proposed solution: HVUC technology

The HVUC project aimed to deliver a level 2 charger that addresses EV ownership barriers around costs and technology shortcomings. The HVUC charger was proposed as a means to deliver energy to EVs more efficiently, more cost effectively, and to provide EV energy use data and visibility to the utility. Given that the majority of British Columbians live in multi-unit residential

housing, and that EV owners prefer the convenience of charging at home or at work, the project aimed to demonstrate that the innovative HVUC charging option can address a key hurdle limiting the adoption of EVs.

The technical goal of the project was to demonstrate that this version of a Level 2 EV charger can eliminate the need of central transformation and provide a number of direct efficiency benefits. The chargers do this by providing local transformation from facility voltage (“high voltage”) by using a solid state or solid state–assisted power conversion topology that includes a utility meter that connects the charger directly to the utility’s smart meter network.

The “utility connected” feature enables arbitration of energy usage between EV drivers and the utility, and enables residential customers in MURBs to take advantage of emerging EV–specific utility programs and rates.

The High Voltage–Utility Connected (HVUC) L2 charger demonstration project supports market transformation towards the use of clean electricity for the transportation sector by eliminating key barriers to electric vehicle (EV) adoption in urban centres. An innovative EV charger design was proposed with a unique high voltage input, integrated power transformation topology, and a utility meter. The plan was to deliver:

- Higher efficiency energy.
- Improved power factor performance.
- Visibility by the utility into EV energy use
- A direct pathway for customer participation in emerging EV specific utility programs.

How the technology works

Circumventing the need for a drop–down intermediary transformer, the charger is fed directly from typical facility voltage (347/600 VAC). The goal is to eliminate the need for a transformer at all, by employing a digitally controlled solid–state, or solid–state assisted power conversion topology to provide local auto–disconnects that remove any quiescent loads from the facility mains when the device isn’t in use. The charger will also auto–disconnect in the event of an overload, eliminating overload propagation upstream. The charger will provide stable output voltage (regardless of the variations in facility voltage), enhancing the efficiency of the on–board EV charger.

Finally, connecting the charger directly to facility voltage allows BC Hydro to install appropriate meters upstream of common area meters, and those meter can be paired directly to a customer account. This metering set–up disaggregates EV–specific energy for the utility, a benefit to energy planning, EV program development, and distribution asset condition management. Among the benefits of direct utility metering are:

- MURB customers can enjoy a lower cost of billing and metering (BC Hydro’s basic charge of \$6 per month, shared with the customer’s main residential account, versus a \$20/month charge by a third–party service).
- Customers can participate in a specific EV rate or other utility programs
- BC Hydro can fulfill its obligation to report transportation loads to the Renewable and Low Carbon Fuel Requirements Regulation.

HVUC development and prototypes

Burnaby–based SMPC Technologies Ltd. has been actively developing the high input voltage charger concept for several years, and has produced early prototypes employing a local auto–transformer power conversion topology. This project focused on solid–state assisted conversion topology as the first step.

Transition to a solid state conversion topology will improve performance and reliability of the charger, and will reduce the cost as power electronics components are expected to continue to come down in price as the technology advances. Meanwhile, the cost of copper transformers remains linked to an in–demand, limited resource.

The specific technical innovations this project addresses are:

- Dedicated utility meters which disaggregate consumption by users
- Solid–state–assisted power conversion
- Auto–disconnect from facility mains.

Project development

The High Voltage Utility Connected (HVUC) Level 2 EV Charging project was defined by the three stages of implementation outlined below.

1. Planning and design definition: Partner work scopes were detailed and contracts established. A Concept Definition Document (CDD) detailed the functional requirements, use cases and key performance indicators (KPIs) for the charger design to comply with project goals. The means of implementing the functional design were evaluated, resulting in a Preliminary Design Specification (PDS). Additional planning was directed towards site hosts engagement, utility policy amendments, coordinating third-party validation and safety compliance certification.

2. Detailed design and validations: Preliminary design considered core charger design and the utility-connected features of the charger. In each case, key utility stakeholders were engaged and consulted.

The detailed design program centred on:

- Electrical design, including power stage and controls
- Mechanical design, including product packaging and mounting accessories
- Software development, including the implementation of SAE J1772 charge port protocol, Open Charge Point Protocol (OCPP) for management and point-of-sale functionality, and OpenADR for demand response capabilities.

Charger certification to governing CSA standards required an extensive audit and test regime. The safety certification process became more extended than planned until all requirements could be met. The charger design benefited from this process, but the extended scope of testing resulted in deployment delays.

3. Production and demonstration: Detailed manufacturing specifications were finalized, and production and assembly were completed. The chargers were assembled locally on site at SMPC, subjected to extensive in-house validation testing, and sent to customers for installation.

Utility policies for direct billing and provision of the load date were amended. The site host engagement process included collaboration with municipalities, local agencies, and installers.

Installers were provided with online and on-site training on the HVUC charger. Individual installation projects were initiated by site hosts, and all the chargers were installed. The demonstration period has been initiated.

Key achievements

TECHNOLOGIES SOLUTIONS TO EV ADOPTION BARRIERS

Most significantly, the project has developed a new topology of Level 2 EV charger that addresses critical market barriers for EV adoption: the installation of chargers in multi-unit residential and commercial facilities and the independent metering of EV energy for direct utility billing. The HVUC charger now provides a solution to incrementally and inexpensively add chargers to multi-tenant or commercial buildings and to disaggregate energy use data from facilities with shared electrical service.

The charger employs internal transformation from commercial facility level voltage (600VAC, 347VAC single phase). This design enables multiple charges to be installed directly to a facility's high-voltage power bus without requiring 240VAC transformation electrical system upgrades. And it eliminates power losses due to underutilized transformer capacity. This design of the HVUC charger provides cost saving to EV owners and shared-facility owners by simplifying charger installation in facilities with common electrical infrastructure, and enables incremental EV charger rollout.

In addition, the HVUC charger substantially disconnects from the power mains when not being used, and therefore eliminates standby power losses entirely. Charger efficiency is also improved by eliminating losses associated with the low-voltage infrastructure required for incumbent chargers.

This project also provided a path forward for the manufacturer for future commercial production of these types of chargers.

The combination of reduced installation and operational costs, as well as the enabling features for energy disaggregation, not only reduces the cost of EV charging, but opens up a substantial customer segment of potential EV drivers living in multi-unit residential buildings (MURBs). This is a significant step in driving EV adoption.

UTILITY POLICY CHANGES

The internal transformer allows the charger to be connected to the 600VAC/main bus, i.e. upstream of the facilities meter, which enables the utility to install dedicated meters for each charger. Prior to this project, such a set-up was only possible for smaller buildings served by 240/208V. This technological advancement, as well as demand generated through this program, prompted changes in BC Hydro's metering policies.

As a result BC Hydro obtained approval from the British Columbia Utilities Commission (BCUC) to provide dedicated metering for EV charging in MURBs. Through collaborations, design approaches were identified that would enable the utility to employ connectivity features to be implemented within the project timeline while simultaneously aligning with core utility modernization roadmaps.

In addition, the project more clearly articulated a need to provide load data to customers. An internal and customer-facing process was put in place to provide aggregated hourly consumption data. Based on the first customer experiences with obtaining hourly load data, several clarifications and internal process adjustments had to be made. Instructions were also posted on BC Hydro's website, and this new process was used to support the provincial EV incentive program (<https://electricvehicles.bchydro.com/charge/tracking-billing-EV-costs-apartment-strata>).

DEMAND RESPONSE

The HVUC charger was designed for compliance with OCPP and OpenADR standards for EV chargers. This technology includes connectivity features that enable direct communication of energy data with the utility, which will enable implementation of demand response programs.

The availability of OCPP and OpenADR capable products in the market triggered several local companies to develop OCPP technologies to provide charger management solutions to customers. During their involvement in this project, BC Hydro subsidiary Powertech Labs received OpenADR certification, and is now able to certify various OpenADR-capable products for compliance with applicable standards.

This project will enable BC Hydro to test OpenADR capabilities in future demand response trials, and also in future integration with its Demand Response Management System.

Challenges

As with any new technologies development and demonstration, several challenges were experienced during this project.

SAFETY CERTIFICATION

The scope of testing and validation required to certify the charger to applicable safety standards proved more onerous and time consuming than anticipated and budgeted for. Custom safety circuits and an environmental enclosure solution created the need for an expanded set of compliance testing and design verification. The expanded certification scope primarily affected project schedule and budget. Certification took longer than expected, delaying charger production and deployment and requiring more investment from the design lead (SMPC).

Cost impacts were minimized through Intertek's participation in the project as a partner providing an in-kind services discount. SMPC provided significantly more in-kind labour contribution than initially planned. A close team coordination further provided regular updates on testing and design priorities to keep the certification process advancing as fast as possible.

MANUFACTURING

Finalizing the production supply chain had its share of challenges, as can be expected in the manufacture of a device. In particular, the charger enclosure was specified as a die-cast assembly to reduce cost and achieve the thermal performance requirements dictated by the internal transformer. Initially an overseas manufacturer was identified but logistics and the small production run made this option non-viable. An alternate local manufacturer was ultimately identified. Production enclosure components demonstrated significant variability and unsatisfactory tolerances, requiring custom finish machining of each part to ensure the integrity of the assembled enclosures. Given the production enclosure was a critical component in final safety certification testing, addressing the manufacturing challenges was a critical path activity.

Ultimately, a method for post-machining cast enclosure clam-shell pairs together was developed to ensure each pair could be assembled within required tolerances. Production of all demonstration units was conducted in this manner, and each charger assembly was completed.

HOST SITE RECRUITING

Recruitment for MURBs relied on installer marketing strategies. Since this was a small pilot, traditional utility-led marketing efforts were not used, as we didn't want to create so much interest that we couldn't meet the demand. As a result, recruitment took longer than expected, but that was balanced by the delays with safety certification. In addition, some participants declined participation as they could not wait for the charger availability. Additional recruitment efforts were undertaken by the installers, and recruitment was expanded to include strata-led installations that didn't require direct billing by BC Hydro.

Knowledge sharing

To date, BC Hydro has promoted the project to local communities via existing networks, such as Metro Vancouver REAC-SPC (a sustainability committee), and the EV Peer Network, a working group of municipal staff, BC Hydro and other policy partner organizations across B.C. that collaborate on EV policy.

Several local governments signed up to be initial funding partners for the project, and site hosts for HVUC public charging stations. These public charging stations were strategically selected to enable MURB residents and commercial/institutional property owners to have access to this innovative technology for future installation at their own facilities.

We have conducted online and in-person training workshops for installers and engineering firms. All Electric Vehicle Supply Equipment (EVSE) installers who are members of the BC Hydro Alliance of Energy Professionals network were invited to participate in the online training to learn about this project and BC Hydro's process to install direct metering for EV charging infrastructure.

We have also partnered with several local engineering firms, who provided detailed electrical plans for the installation of these chargers. Interested installers and engineers directly involved with this project receive in-person training from the manufacturer on the installation of the product.

The manufacturer planned to showcase this charger at the 100th anniversary of the Vancouver International Auto Show in March of 2020, but the show was cancelled due to the COVID-19 pandemic. Once similar opportunities become available, more public outreach activities will be planned.

As the demonstration and data collection phase of the project has just begun, there will be a five-year period of performance monitoring before quantified results and impacts of the program can be shared.

Key benefits for stakeholders

Potential stakeholder benefits of the project include:

- A Level 2 EV charger technology that reduces barriers to EV uptake by Canadians living in MURBs can translate into a reduction in the reliance of harmful transportation-related emissions.
- A direct pathway for customer participation in emerging EV-specific utility programs related to demand response and load control. The technology will be replicable in other Canadian and international jurisdictions.

So far, the project has developed and deployed a novel L2 charger that can enable cost effective installation and direct utility connection for the large underserved market segment of potential EV owners who live in multi-unit residential buildings (MURBs). It can also serve the needs of large commercial facilities serviced by 600VAC.

The deployment of 60 chargers in a variety of public, commercial and MURB location has demonstrated a technical solution for providing MURB residents with at-home charging capabilities for EVs. This will serve as a template for promoting the solution and engaging increase adoption of EVs.

Over the coming demonstration phase, the impact of enabling EVs in these project locations will be quantified in terms of the number of plug-in electric vehicles involved, and the calculated GHG emission savings related to a switch to EVs. These direct project benefits can then be forecast more broadly over the potential increase in EV adoption enabled by the project.

In the long-term, the project is expected to lead to large and sustained GHG and criteria emission reductions in BC related to greater EV adoption in the MURB market, which accounts for the majority of British Columbians.

The project has already demonstrated the first-ever utility-connected solution suitable for MURBs and commercial buildings in B.C.. These immediate successes will be leveraged more broadly in the coming years to promote further EV adoption in underserved market areas.

Policy impacts

A variety of federal, provincial and local policies had a positive impact on this project. In return, the project will provide support for future federal, provincial and local policies that help enable EV adoption.

The project is complementary to and leverages both provincial and federal EV incentives. The HVUC installations in MURBs were made possible by the provincial EVSE incentive programs.

The new HVUC charger installations triggered metering policy changes adopted by BC Hydro. These policy changes were in turn supporting the rollout of the provincial EV charging incentive program delivered by BC Hydro.

Many local governments have adopted and are continuing to adopt EV-ready policies in new residential and commercial construction. The HVUC charger will help developers and property managers comply with these policies, and in turn will support incremental EV adoption. This opens the door for various jurisdictions to explore EVSE policies for existing buildings.

The BC ZEV mandate, carbon pricing, and federal and provincial vehicle incentive policies serve as an underlying framework for driving EV adoption. That will only serve to drive increased demand for EVSE and technologies such as the HVUC charger.

Similarly, the availability of technologies such as OCPP and OpenADR will provide the base for future utility demand response programs, and for potential policy changes such as time-of-use rates.

Timeline and budget

The project received full approval from Natural Resources Canada in October 2017, and was completed in June 2020. This included a one-year extension to accommodate the longer than expected safety testing process.

The project is on budget as planned for \$2.4M, with 50% funding provided by NRCan's EVID program, and the remaining amount contributed by the manufacturer SMPC. Due to the extended certification process, contributions by SMPC were significantly higher than expected. Some local government installation costs also exceeded originally planned amounts due to site-specific challenges.

Next steps

The HVUC chargers have been deployed to customer sites in public spaces, commercial buildings and MURBs. Over the coming years, the project team will continue to acquire data and feedback from customers to quantify the projected benefits of the chargers and their impact in promoting wider EV adoption in underserved market segments.

The project has developed a data portal to track charger performance and usage data for all networked connected chargers. Data will be collected as authorized by charger owners and operators. The project will also collect feedback from users and stakeholders on relative installation and operational costs to further evaluate the charger's value proposition.

The newly introduced utility direct metering policy has and will continue to serve as a pilot for utility programs aimed at EV drivers. BC Hydro will utilize the installed HVUC chargers to test demand response capabilities enabled via the OpenADR protocols implemented in the chargers. This aligns with future utility services roadmaps to adopt and roll out demand response programs more broadly over the service network.

The success of the charger will be leveraged by SMPC to further develop a commercial offering. Design improvements and cost-down measures have already been initiated. It's expected that the project will serve as a catalyst for the broader rollout of commercial offerings of the HVUC design in different jurisdictions.