CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Manufacturing Refinements for the ChargePoint Communication Processor

Prepared for: California Energy Commission

Prepared by: ChargePoint, Inc.

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program, formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued solicitation PON-09-605 "Manufacturing Plants: Electric Vehicles, Alternative Fuel Vehicles, Vehicle Components and Batteries" on April 8, 2010 to provide funding opportunities under the Clean Transportation Program for the development and expansion of manufacturing and assembly plants in California that produce electric vehicles, batteries, and component parts for alternative fuel vehicles. In response to PON-09-605, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards on July 30, 2010. The agreement was executed as ARV-10-012 on February 28, 2011.

ABSTRACT

With funding from the California Energy Commission, ChargePoint developed hardware and software and refined manufacturing methods for the ChargePoint Communication Processor that is integrated with electric vehicle charging stations produced by other component manufacturers.

Keywords: ChargePoint Communication Processor, electric vehicle, electric vehicle charging station, EV charger, smart grid, load management.

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EXECUTIVE SUMMARY

As more electric vehicle charging stations are installed, a key greenhouse gas (GHG) reduction benefit is lost if those electric vehicle stations are not integrated into a smart grid and cannot provide peak load management functions. The ChargePoint Communication Processor can be used to remotely control charging of electric vehicle batteries to shift loads away from peak hours, when electricity generation produces higher levels of GHGs due to natural gas-fired peaker generating plants coming online. ChargePoint's California-based technology can be modified to be integrated with multiple electric vehicle chargers, minimizing the time to shift load, and capturing GHG reduction benefits.

The goal of the project was to refine manufacturing methods for the The ChargePoint Communication Processor that would enable integration with the variety of electric vehicle charging stations manufactured by other manufacturers. The technology provides demand response and peak load management capabilities for all charging stations

The objective of the agreement was to develop hardware and software that was compatible with both the ChargePoint Network Operating System and the electric vehicle charging station. The project was also designed to establish a pilot-build of a The ChargePoint Communication Processor that would pass external third party testing and to be ready for commercial production.

ChargePoint successfully designed, developed, and tested the The ChargePoint Communication Processor. ChargePoint built the pilot board and developed refinements to its manufacturing process. ChargePoint also integrated the board and software with other electric vehicle charging station manufacturers such as Eaton, Fuji, DBT, Nissan and Schneider Electric. The technology was integrated into four Level 2 charging stations and three DC fast chargers. The result of the project was commercial production of the communication board.

CHAPTER 1:
Background

Background

The electric utility grid is approximately one hundred years old. The grid architecture is generally hierarchical, with a smaller number of energy generation sources and a larger number of energy sinks or consumers. The electric grid was not designed to incorporate stochastic and small renewable energy sources such as solar energy from residential rooftops, nor was it meant to integrate demand response or to integrate smart devices or smart electric cars into the grid. ChargePoint has learned that smart systems have the ability to make decisions, store information, learn by experience, and self-adapt and self-heal. Energy is the essential entity that is being manipulated; its generation, movement, storage, control, consumption, reuse, routing, etc., are the most important focal points for the project.

A smart charge network will create a much larger network for electric vehicle (EV) charging stations that minimizes the impact to the electric grid, enables the use of EV's and provides the opportunity for EV drivers to charge their vehicles at a variety of stations networked to provide easy access and billing.

ChargePoint

ChargePoint is a major supplier in the Level 1, Level 2, and Level 3 Electric Vehicle Supply Equipment (EVSE) marketplace. ChargePoint's billing system, driver support applications, Smart Grid integration, and remote monitoring and maintenance allow for complete data collection. This data will be important to the state as EVs enter the marketplace.

CHAPTER 2:
Project Description

California Energy Commission (CEC) funding from this grant was used to refine manufacturing methods for the CPCP to allow integration with EV charging stations produced by other manufacturers. The technology enabled these stations to manage load shifts using the ChargePoint network. The project developed prototype hardware and software, identified needed manufacturing refinements, and developed a pilot of the The ChargePoint Communication Processor (CPCP) integrated with stations manufactured by others.

Project Goals and Objectives

Operational goals of the project were to cost-effectively:

- Integrate with the smart grid; provide a number of peak load management functionalities to better utilize the grid and, hence, save on expensive peaker plant generation construction and GHG emissions;
- Provide for optional billing functionality so that the ongoing cost of electricity and equipment can be recovered by the host;
- Provide for large scale wireless monitoring and management services;
- Provide for data, fault, and alarm conditions services to the host;
- Provide for web-based services to the end customer.

Project objectives were to:

- Develop hardware and software compatible with both the NOS and the EV charging station;
- Successfully establish communication with the NOS and cellular connectivity through at least two providers;
- Establish a pilot build of CPCP that passes external third party testing and is ready for commercial production;
- Provide low cost, local manufacturing facilities for the CPCP;
- Provide low cost and timely methods for vendors to develop smart charging station solutions.

Summary of Key Technical Tasks

Task 2: Develop Hardware and Software to Inform Manufacturing Refinements

The goal of this task was to redesign and refine the manufacturing of ChargePoint's existing CPCP to enable integration with EV charging stations manufactured by other companies.

The specific activities conducted by ChargePoint in this task were to:

- Draft design specifications for the communications board and engage with third party cellular design service;
- Complete schematic for the communications board;
- Complete layout of the communication board and acquired necessary test equipment;
- Fabricate and assemble prototype communications board.
- Complete board testing and hardware and software integration;
- Integrate with Eaton 30A Level 2 (L2) single port, Eaton L2 dual port, Eaton 70A single port Eaton Level 3 (L3), Fuji L3, DBT L2, and Nissan L3 charging stations;
- Make software modifications for integration including Modbus register map, Start/Stop/Get messages with EVSE, Zigbee, display for test messages, Code Division Multiple Access / General Packet Radio Service modem, auto-detected modem with EVSE, reservation feature, access control list, over-the-air feature, double pump feature, credit card processing feature, per kilowatt hour (kWh) pricing feature, and dual port register map;
- Complete installation of the electrical facilities for testing L3 charger;
- Integrate with L2 and L3 charging stations.

TASK 3: Conduct Quality Engineering and Quality Assurance

The goals of this task were to ensure the proper functioning of the integrated system and to conform final modifications to the manufacturing methods.

The specific activities conducted were to:

- Test CPCP by testing communication and policy enforcement with the NOS for all charging stations;
- Test client-server policy enforcement from the NOS with integrated EV charging station;
- Complete quality assurance testing and regression testing for all EVSE's and release to production;
- Test cellular connectivity and certify with three wireless carriers.

TASK 4 Implement Pilot Project and Final Manufacturing Refinements

The goal of this task was to complete a pilot build of the CPCP and EV charging stations and identify final modifications to ChargePoint's manufacturing methods to enable full production.

The specific activities in this task were to:

- Complete initial pilot build of the integrated CPCP and EV charging stations;
- Initiate production build;
- Complete first article inspection - an internal ChargePoint product development process;
- Send units to pilot sites for external testing including Eaton, DBT, Fuji, Schneider and Nissan;

- Complete integration of the pilot board and software with Eaton, Fuji, DBT, Nissan and Schneider charging stations. Modified board to fit the manufacturer's requirements and final modifications were made for manufacturing. Manufactured pilot boards and production boards in San Jose, CA.

TASK 5 Data Collection and Analysis

The goal of this task was to identify economic benefits and local impacts of the project throughout the term of the project.

CHAPTER 3:
Results and Conclusions

Results

ChargePoint has learned from the project. Results and learnings include:

- The communication board was designed, manufactured and seamlessly integrated into other manufacturers' charging stations.
- Integration was challenging, but ChargePoint engineers were able to successfully integrate the CPCP into charging stations.
- Increased interest from other charging station manufacturers to participate in the project or in subsequent ones.
- Increased knowledge and understanding of the range of charging station issues from other manufacturers.
- Increased knowledge of the process and time required to install charging stations.

Figure 1: ChargePoint Communication Processor

Photo Credit: ChargePoint

Conclusions

ChargePoint is pleased with the funding of the project and project results. ChargePoint was able to make other manufacturers' charging stations smart grid ready.

The project created multiple benefits for industry, consumers and the environment.

Industry Benefits

1. The funding advanced the technology development of the communication board and its software, which allowed for better integration with other manufacturers' charging stations. This expands the number of charging systems that are smart grid ready and integrated with L2 and DC fast charge stations.
2. The project helped the EV industry better manage energy consumption from the charging stations.
3. The project helps the electric grid by managing the EV charging load.
4. The project benefits California utilities by providing much needed networking capabilities as EV sales increase.
5. The development of a networked, smart grid charging program may help reduce the need to build new fossil-fired generating plants; which could reduce CO2 emissions.
6. All the ChargePoint enabled charging stations are now capable of demand response and peak load management capabilities.
7. The success of the project enabled early commercial production of the technology. Over 200 charging stations have been manufactured and deployed. This has resulted in technology advancements to come to market that benefit the whole industry.

Environmental Benefits

1. Increased use of ChargePoint's technology to fuel EVs will lead to reductions in oil consumption and imports. As California is a large market for petroleum fuels, a reduction in demand for petroleum will decrease the volume of oil imports, improving national security and strengthening the economy.
2. Assuming that charging power is drawn from non-polluting sources, the project would displace 12,250 gallons of gasoline and avoid the emissions of 41,004 kilograms of GHGs. US EPA's formula was used in the calculation of GHG savings and gasoline displaced.
3. The carbon intensity for gasoline is higher than electricity. Assuming that all non-petroleum transportation fuels can generate emission reduction credits under the LCFS, then fueling with electricity would create a large number of LCFS credits per vehicle-mile.
4. The project has led to a new smart charge program which further supports the transition from our present unsustainable transportation system – which involves insecure and costly reliance on foreign fuel sources – and dangerous and unhealthy burning of limited fossil fuels – to a sustainable electrified transportation system based on clean and renewable fuel sources.

5. While oil supplies are subject to a wide range of geopolitical risks, the fuels used to generate electricity are generally sourced domestically. California's electricity is generated from a diverse set of largely domestic fuels, including uranium, natural gas, flowing water, wind, geothermal heat, the sun, landfill gas and others, making it a domestic fuel.
6. The NOS EV charging systems will promote environmental quality by allowing customers to purchase cleaner, lower-carbon-emitting electricity from an array of renewable energy sources, and allow access to more environmentally-friendly central station generation. Furthermore, a networked EV charging system will allow for more efficient consumer response to prices, which will reduce the need for additional fossil fuel-fired generation capacity, thereby reducing the emission of CO2 and other pollutants.

From an environmental standpoint, EV's are much cleaner than conventional vehicles, particularly for pollutants such as nitrogen oxides (NOx), volatile organic compounds (VOCs), fine particulate matter (PM2.5) and carbon monoxide (CO). EV's also reduce emissions of GHGs. By reducing these emissions, EVs may reduce regulatory compliance cost pressures on stationary sources. Those sources, facing lower compliance costs, would be able to redirect those cost savings towards employee compensation, capital investment, and other productive uses.

Consumer Benefits

1. Lower levels of transportation-generated particulate and criteria emissions will reduce pollution-related health effects and create health care cost savings.
2. Networking EV charging systems can create benefits through improvements in grid reliability by reducing the frequency and duration of power outages and the number of power quality disturbances, including reducing the probability of regional blackouts.

Business and Economic Development Benefits

1. ChargePoint, Inc. is a California-based firm, located in Campbell, California currently employing over 100 people. The project sustained ChargePoint's ability to retain these current jobs and through the commercialization of this new technology, create new ones.
2. ChargePoint's ability to export products and services provides economic benefits to California. The CPCP contract manufacturer is located in San Jose, California and manufactures ChargePoint's communication board. The primary job types directly created or retained by the project is in engineering and manufacturing (hardware, operations and software). Fifteen ChargePoint employees worked on the project directly and several others worked indirectly on the projects that support local economies for the duration of the project term.
3. New jobs were created in the battery manufacturing industry and in the construction, operation, and maintenance of an EV charging infrastructure network in many communities throughout California. Each commercial charging station installation requires on average 16 hours installing a charging station.

4. The installation of the charging stations created electrician and construction jobs,
5. Private capital over $1.1 million was leveraged directly for the project. The project also inspired additional private investments for the manufacturing and purchase of charging stations.
6. From a micro-economic standpoint, electricity prices are significantly less volatile than gasoline prices. Over the past 25 years, electricity prices have risen steadily but slowly. Electricity prices have risen by an average of less than two percent per year in nominal terms and have actually fallen in real terms. The price of gasoline, on the other hand, is expected to rise at a higher rate.
7. The project helps support increasing EV sales in California, accounting for 50 percent of total national EV sales.
8. ChargePoint successfully completed the project with its 2nd generation communications board manufacturing. ChargePoint recommends that the CEC fund the 3rd generation communications board manufacturing.

Achieving Operational Goals

ChargePoint's operational goal was to modify three charging stations from collaborating manufacturers with the CPCP technology. ChargePoint exceeded these goals and modified 8 charging stations from 5 manufacturers (Eaton, DBT, Fuji, Schneider and Nissan). Currently, over 200 charging stations are manufactured and deployed by five manufacturers. The stations are deployed in California, Washington, Arizona, Colorado, Texas, Illinois, Michigan, New York and Florida. Figure 2 is the map of the deployed stations in 2012.

Figure 2: National Map of EV Charging Stations in 2012

Source: Chargepoint

Project Challenges

Initially, ChargePoint planned to install the CPCP boards for three charging stations and three manufacturers. The high demand from other manufacturers expanded the project and ChargePoint installed the boards on eight products from five manufacturers, which required more resources for testing and integration.

ChargePoint paid for some services, which included wireless certification, board and manufacturing costs, travel expenses, and shipping costs for boards. ChargePoint also received equipment from manufactures, which otherwise would have be expensed to the grant.

During the project, ChargePoint requested a formal amendment from the CEC to reallocate $248,836.00 from operating expenses to personnel expenses. Additionally, the original match funding was $1,103,076 which was increased to $1,143,028 due to match support received from new project partners (manufacturers).

GLOSSARY

CALIFORNIA ENERGY COMMISSION (CEC) - The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

- Forecasting future statewide energy needs
- Licensing power plants sufficient to meet those needs
- Promoting energy conservation and efficiency measures
- Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels
- Planning for and directing state response to energy emergencies.

CARBON DIOXIDE (CO2) - A colorless, odorless, non-poisonous gas that is a normal part of the air. Carbon dioxide is exhaled by humans and animals and is absorbed by green growing things and by the sea. CO2 is the greenhouse gas whose concentration is being most affected directly by human activities. CO2 also serves as the reference to compare all other greenhouse gases (see carbon dioxide equivalent). The major source of CO2 emissions is fossil fuel combustion. CO2 emissions are also a product of forest clearing, biomass burning, and non-energy production processes such as cement production. Atmospheric concentrations of CO2 have been increasing at a rate of about 0.5% per year and are now about 30% above preindustrial levels. (EPA)

CHARGEPOINT COMMUNICATION PROCESSOR (CPCP) – Name of ChargePoint's proprietary communication system for networking EV chargers.

DIRECT CURRENT (DC) - A charge of electricity that flows in one direction and is the type of power that comes from a battery.

ELECTRIC VEHICLES (EV) -- A broad category that includes all vehicles that are fully powered by Electricity or an Electric Motor.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) - The conductors, including the ungrounded, grounded, and equipment grounding conductors and the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the electric vehicle.[1]

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1 Electric Power Research Institute. Article 625 "Electric Vehicle Charging and Supply Equipment Systems." Section 625.2 – Definitions.
http://mydocs.epri.com/docs/publicmeetingmaterials/1112/PDNNSH5Q3Z2/Day%201%20PlugIn%20Electric%20Vehicle%20Codes%20Standards/D1_7C%20G%20Kissel%20Article%20625%20Restructure%20Proposal.pdf

GREENHOUSE GAS -- Any gas that absorbs infra-red radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), halogenated fluorocarbons (HCFCs), ozone (O3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs). (EPA)

KILOWATT-HOUR (kWh) -- The most commonly used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumes 534 kWh in an average month.

LOW CARBON FUEL STANDARD (LCFS) -- A set of standards designed to encourage the use of cleaner low-carbon fuels in California, encourage the production of those fuels, and therefore, reduce greenhouse gas (GHG) emissions. The LCFS standards are expressed in terms of the "carbon intensity" (CI) of gasoline and diesel fuel and their respective substitutes. The LCFS is a key part of a comprehensive set of programs in California to cut greenhouse gas emission and other smog-forming and toxic air pollutants by improving vehicle technology, reducing fuel consumption, and increasing transportation mobility options. NETWORK OPERATING SYSTEM (NOS) – ChargePoint's proprietary software for the operation of its EV charging stations and systems.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA) -- A federal agency created in 1970 to permit coordinated governmental action for protection of the environment by systematic abatement and control of pollution through integration or research, monitoring, standards setting and enforcement activities.