OPAL-RT AND NI SOLUTION HELPS TO ENGINEER DC FAST-CHARGING SYSTEMS FOR EVs ON THE TRANS-CANADA HIGHWAY

UNIVERSITY OF TORONTO

ecamion
POWER OVER ENERGY

Application

- Electric Vehicle Charging Stations

Related Products

- OPAL-RT FPGA-Based Power Electronics Toolbox (eHS)
- NI LabVIEW
- NI cRIO-9082

Type of Simulation

- Hardware-in-the-Loop (HIL)
- Rapid Control Prototyping (RCP)

OPAL-RT TECHNOLOGIES

SUCCESS STORY

INTRODUCTION

Electric Vehicles (EVs) have until now taken far longer to recharge than it takes to fill up a tank of gasoline, and yet they're becoming very popular. The missing piece has always been a fast recharge, say 20-30 minutes. This solution has been slow to evolve, because the existing infrastructure was not engineered for this challenge — either in speed or volume of electricity delivered.

Enter University of Toronto's Centre for Applied Power Electronics (CAPE), partnering with energy storage company eCAMION, in one of Canada's most ambitious EV infrastructure projects: build a DC Fast-Charging System (DCFCS) for EV charging stations on the Trans-Canada Highway: one of the longest highways in the world with a length of 7,821 km[1].

Team members of eCAMION and University of Toronto's Centre for Applied Power Electronics (CAPE)

CHALLENGES

The very concept of fast charging implies a large amount of energy in a short time (it's a bandwidth or throughput issue). University of Toronto's Professor Reza Iravani and his team from CAPE considered a new model, where electricity is stored in and discharged from local high-capacity batteries that are then refilled by the pre-existing infrastructure between users. These local battery storage units then become part of a larger system to reduce the impact of DC Fast-Charging Systems on the electrical infrastructure.

While this seemed to solve the throughput issue, the engineering challenges remained.

ELECTRIC GAS STATIONS

"...The idea here is to have large-scale, utility-grade battery systems to charge EVs," says Iravani. *"Drivers would charge their EVs from these large batteries—think of them like gas stations—in several minutes, and these stationary batteries would be gradually charged from the grid, based on the existing grid capacity.[2]"*

Dr. Reza Iravani - University of Toronto's Professor in the Department of Electrical & Computer Engineering (ECE), and founder of the CAPE

OBJECTIVE

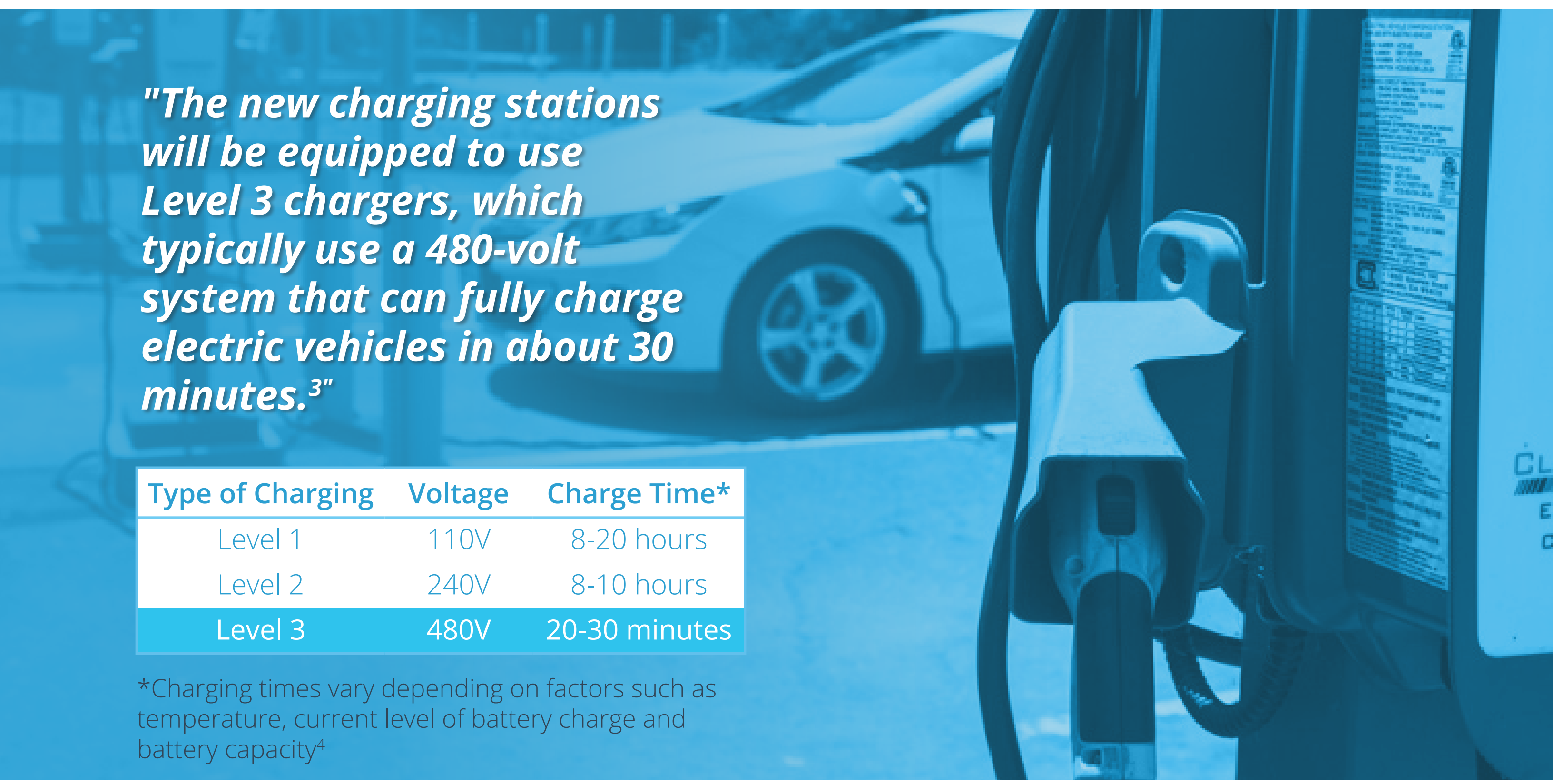
As the first and determining part of their challenge, CAPE's team needed to develop control algorithms for their DC Fast-Charging System (DCFCS), along with a local large-volume battery storage system. They decided to deploy the control algorithms on a cRIO-9082, a National Instruments' embedded controller (EC) for real-time simulation. When it came to the battery storage system, they partnered with eCAMION, a Toronto-based company with accumulated expertise in developing solutions for issues specific to EV adoption in existing infrastructures.

They also needed to simulate the power electronics model for the fast chargers, configure the power electronics converter, fine tune its controller design and complete development with a 60-kW prototype.

Due to the need for two fast-charging sequences (one from battery to car, the other from grid to battery afterwards), CAPE's team had to achieve higher-charging voltage by connecting two chargers in series, and implementing the Local Controller (LC) on the cRIO-9082.

Additionally, they had to develop and test (in real time and through HIL simulation) the Local Controller of the grid-interface's AC/DC converter on NI's cRIO-9082. Finally, they had to develop the Supervisory Control (SC) that coordinates the stations' Local Controllers.

Each new station was designed to consist of an energy storage system that uses large-format lithium-ion batteries and multiple outlets so that several cars can be charged at once. The stations are to be equipped to use Level 3 chargers, which typically use a 480-volt system that can fully charge electric vehicles in about 30 minutes. Level 2 chargers, found in homes and commonly seen in parking garages, use a 240-volt system and can fully recharge vehicles in about 8 to 10 hours.[3]

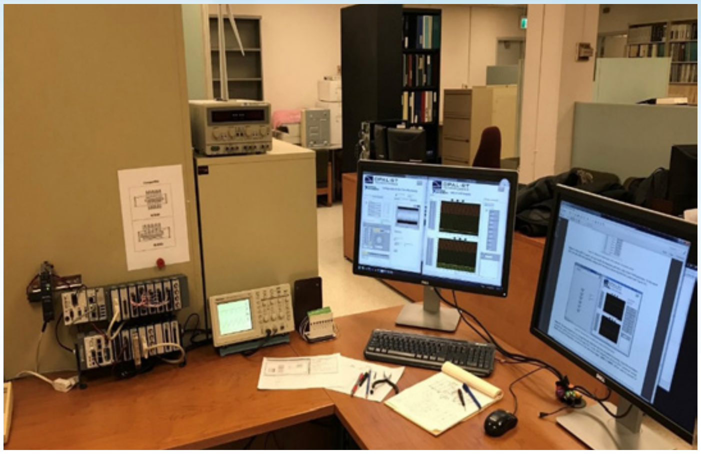


"The new charging stations will be equipped to use Level 3 chargers, which typically use a 480-volt system that can fully charge electric vehicles in about 30 minutes.[3]"

Type of Charging	Voltage	Charge Time*
Level 1	110V	8-20 hours
Level 2	240V	8-10 hours
Level 3	480V	20-30 minutes

*Charging times vary depending on factors such as temperature, current level of battery charge and battery capacity[4]

SOLUTIONS & DEVELOPMENT

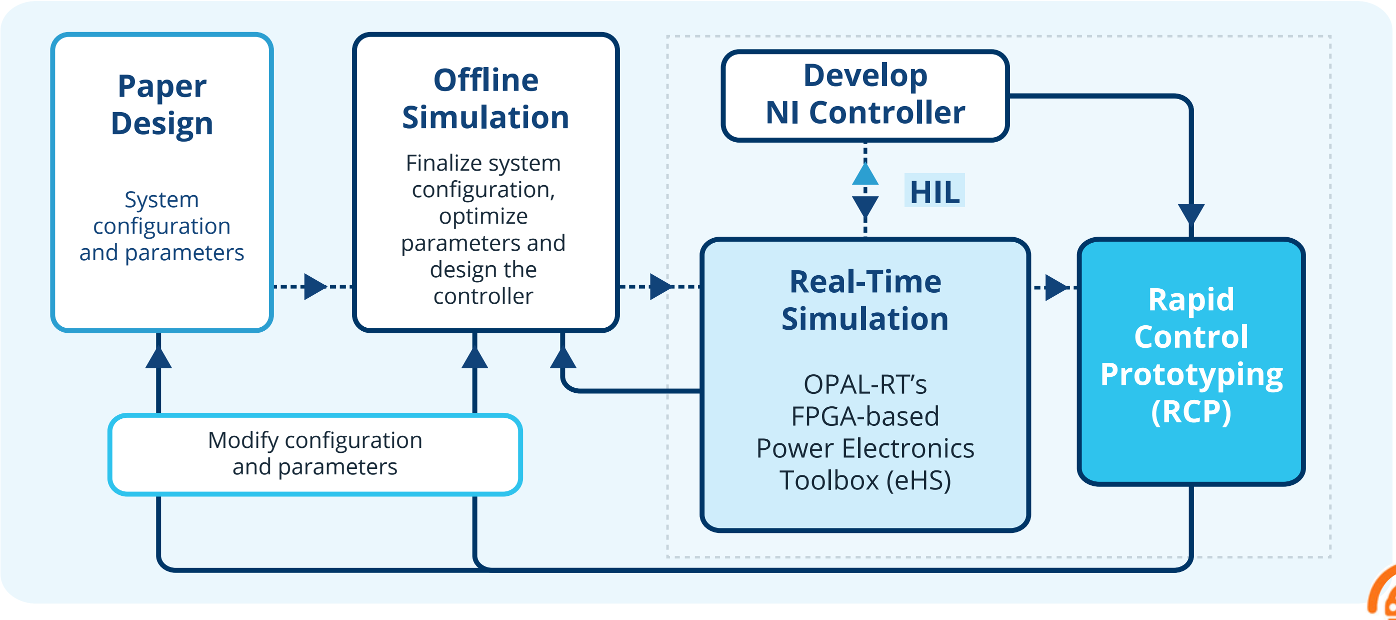


After starting the development process on paper to determine system configuration and parameters, CAPE's team went to offline simulation for finalizing the configuration, optimizing the parameters, and designing the controller.

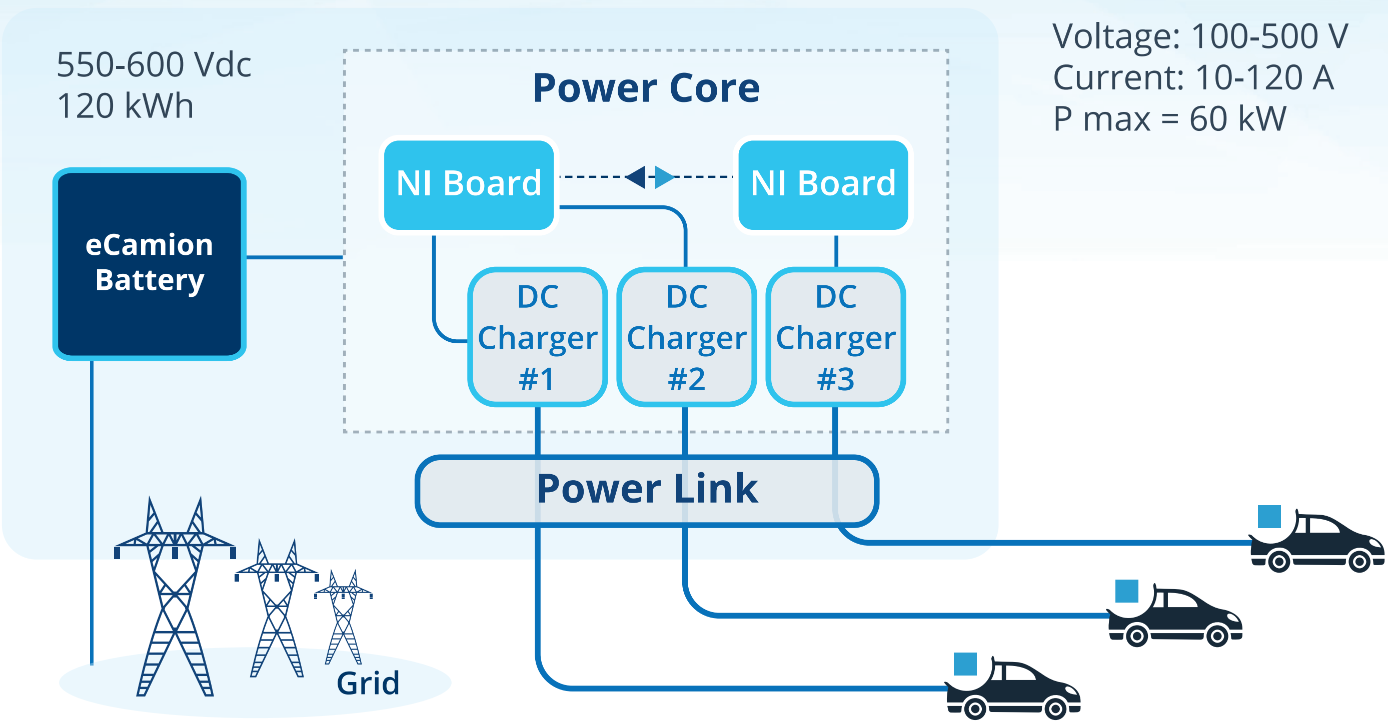
They then went to OPAL-RT FPGA-Based Power Electronics Toolbox (eHS), for real-time simulation of the controller.

At this stage, an actual NI controller was introduced and simulated through HIL testing. In turn, this NI controller underwent Rapid Control Prototyping (RCP) to ensure that it functioned as required. This process was heavily iterative and alternated between simulation types as lessons learned from various stages were integrated into further testing iterations.

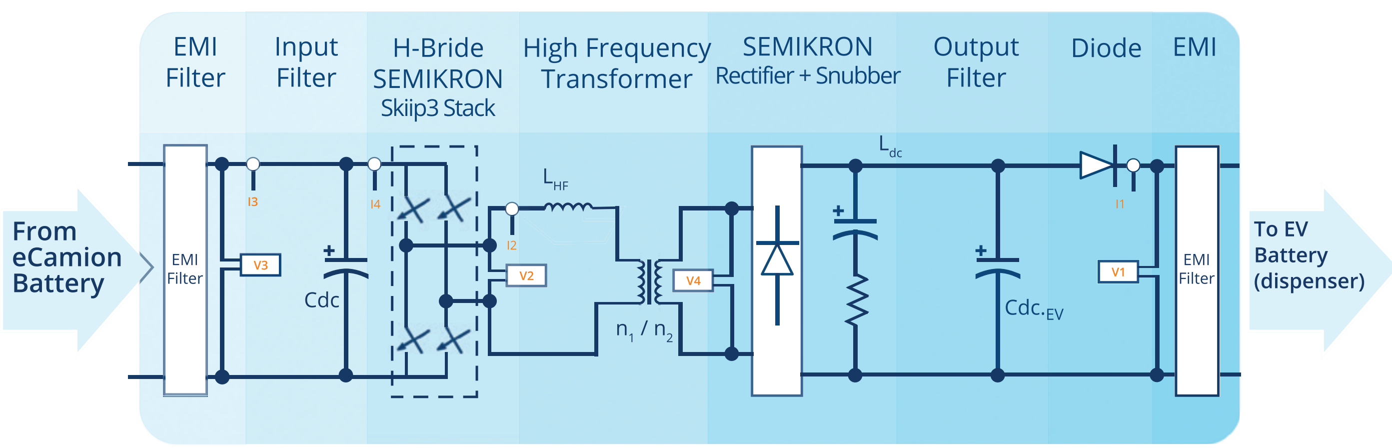
DEVELOPMENT PROCESS



CHARGING STATION: THREE CHARGER UNITS



CIRCUIT ELEMENTS OF ONE CHARGER UNIT (POWER CORE)



RESULTS

The final product was UL and ESA approved.

The final converter had been developed in less than two years (January 2018 to June 2019) and its final configuration involved:

- An isolated DC-AC-DC converter that enabled serial/parallel configuration at the EV end.
- 10 kHz in switching frequency that reduced the size of the output filter and the magnetics
- A phase-shift gating control strategy that provided soft-switching conditions
- Unidirectional power flow from the H-bridge at the front end and diode rectifier at the EV end

CONCLUSION

OPAL-RT's FPGA-based Power Electronics Toolbox (eHS) —used throughout the course of the development of the units— allowed the engineers to, in their own words:

- EXPEDITE the development process
- LOWER the development costs
- REDUCE the safety risks inherent in developing the systems at high voltage and currents

Project organizers estimate the EV charging network will reduce emissions by an estimated 0.7 million tonnes over the first five years of its operation[5].

OPAL-RT thus played a central role in **one of the most ambitious EV infrastructure projects yet to take place, worldwide**, through its FPGA-based Power Electronics Toolbox (eHS).

OPAL-RT hosted a webinar that had the participation of team members of the University of Toronto (Dr. Ali Nabavi and Mostafa Mahfouz), and eCAMION's VP Engineer (Rick Szymczyk).

This project received funding through the TargetGHG program, funded by Ontario's Ministry of Research, Innovation and Science (MRIS) and administered by Ontario Centres of Excellence (OCE), and through the Natural Sciences and Engineering Research Council of Canada (NSERC) as well as from eCAMION6, totalling $2.4M over three years.

1 https://www.roadtraffic-technology.com/features/feature-the-worlds-longest-highways/

2 https://news.engineering.utoronto.ca/reducing-range-anxiety-electric-vehicles-speeding-charging-time/

3 https://www.ecamion.com/fast-charging-stations-for-electric-vehicles-coming-to-trans-canada-highway/

4 http://www.mto.gov.on.ca/english/vehicles/electric/charging-electric-vehicle.shtml

5 https://www.canadianmanufacturing.com/manufacturing/energy-storage-firms-building-ev-charging-network-along-trans-canadahighway-197770/