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Community Energy Storage

How eCamion Created an Urban First

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eCamion, Toronto Hydro, Dow Kokam and the University of Toronto have put theory into practice with the first CES system to be installed directly into an urban community. Lynnda Greene reports.

Coming soon to a street near you

Only a few years ago, Community Energy Storage was little more than a novelty, a small scale energy storage concept developed by researchers for possible integration into large utility grids.

But that's all changed.

Today, CES is starting to be seen as a game-changer and Canadian firm eCamion has deployed both a global first and the smallest CES footprint for the power it generates. It's a key element in a smart energy plan that could serve utilities' needs to maintain power quality and consistency, conserve its use, and generate more energy from renewable sources.

But, despite increasing interest, to date the few small demonstration projects have done little more than help understand CES's potential to address a wide range of issues, including peak load shaving, voltage support, frequency regulation and the possibility of islanding in the event of outages.

None, however, has attempted to take the next step: a large scale CES installation that, fully integrated into a large municipal utility grid, can support an entire residential street.

In February 2013, Toronto Hydro, a municipal electric utility serving more than 700,000 customers and a population of 2.8 million people, and eCamion, Dow Kokam and the University of Toronto unveiled what could transform its own intelligent grid strategy and — perhaps — the entire utility industry: the first CES system to be installed directly into an urban community.

The system is located in the Rodding Arena and Community Centre in North York, Ontario. It provides 250kWh/500kW of storage and requires little more so-called 'pad-mount' space than a normal Toronto Hydro transformer. The lithium polymer batteries are housed in a storage system of battery modules monitored by a battery management system and related thermal management communications and smart control mechanisms.

Most particularly it offers distributed intelligence — effectively it optimizes its functionality as it interacts and operates on the grid.

Fully charged, it can provide electricity to a typical community centre, a light industrial complex or small residential street of homes for as long as three hours; providing temporary relief during power outages.

The project has received funding through several sources, including Sustainable Development Technology Canada (SDTC) which has a mandate to commercialize cleantech.

eCamion designed and integrated the storage system. Its management communications and controls use lithium-polymer NMC (nickel manganese cobalt) cells.

Toronto Hydro provided the connection point within the local distribution system.

The cell chemistry was developed by Dow Kokam.

"What we wanted to do was build a CES system large enough to support a residential street in the event of an outage — as well as facilitate enough system flexibility to offer utilities new options in meeting pressing needs"

A team of researchers from the University of Toronto developed the CPPM (Control, Protection and Power Management) technology and built the algorithms that integrate the system with the grid.

This was a difficult project to pull together given the number of technologies, disciplines and collaborators involved.

Utilities, although aware of the possibilities that CES could offer, have been understandably cautious about its deployment wanting first to fully understand how — and in what capacities — the technology can serve their needs.

Given that many grid systems are so old that adequate updating will require massive capital investment, utilities are questioning the wisdom of spending millions on major equipment updates. They wonder whether spending a fraction of this on CES installations could help defer costs by many years.

From conception to execution

The concept of CES was developed by leading industry figure Larry Dickerman, then of DNV KEMA, early in the last decade.

"The original idea," Dickerman told *Batteries International* in a recent interview, "was to use the kind of battery used in the Chevy Volt or the Nissan Leaf, and instead connect them to grid. It was basically connecting multiple 25kwH-75 kWh battery energy storage units to utility transformers to achieve levelling and peak shaving at the sub-station level.

"And how it got its name? One day a fellow who worked in our office on this project came in said to us, what are we going to call this? This would have been about 2006. Well what do you want to call it? So we came up with Community Energy Storage, CES, and it's stuck.

"A CES unit would be the size where it could actually sit beside the transformer that serves that group of customers, and it would provide some degree of reliability when the power goes out."

One of the first CES systems was installed by AEP of Ohio in two demonstration units in 2006. Placement of a few small scale demonstration projects in selected US cities followed, but no commercial installations of any significant scale were attempted.

That's what interested Carmine Pizzurro, the founder of eCamion, who saw that the CES concept could be

The Toronto Hydro project is important from a data-gathering perspective to qualify its benefits. "What we learn from this, I believe, will move Intelligent Community Energy Storage to the forefront of Utilities capital expenditure" — Hari Subramaniam, eCamion

GETTING THE MESSAGE ACROSS

One of the strengths of eCamion's CES design is that it can be adapted to a variety of applications. In the next year or so eCamion says it will be working with new clients on projects for up to 5MW of CES units with five or six utility partners in North America.

Oddly enough, despite the new business for eCamion, one of the next challenges may be less technological and more educational — marketing in other words.

At a practical level Hari Subramaniam, chief executive of eCamion says, "Five points need to be conveyed in in building the value proposition with our partners," he says.

"It has to enable integration of renewables, defer investment costs from infrastructure, provide voltage/VAR support, assist with power quality while being able to monetise on ancillary services such as frequency regulationAnd the message that needs to be conveyed is not just to utilities, or local communities but policymakers in local and national government.

The announcement by the Ontario energy minister in early December that the Canadian province's Long Term Energy Plan would include storage technologies in the procurement process "starting with 50MW and assessing additional engagement on an ongoing basis" represents a milestone in acceptance of CES.

eCamion was a founder of the Ontario Energy Storage Alliance, the lobbying body behind the change.

As for how rapidly these grid storage technologies will be adopted by utilities, much may depend on regulatory changes, Subramaniam says. "There are a number of state and provincial initiatives underway to set targets for storage, most recently in California. Mandates and regulation changes by government may encourage and induce utilities to adopt more intelligent storage assets."

CES SYSTEMS: THE BENEFITS

- Improves power quality, energy flow and reliability.
- Reduces peak demand and offer temporary relief in neighbourhoods at risk to help prioritize and defer capital investment.
- Reduces the need for diesel generators.
- Facilitates the integration of renewable technologies and electric vehicles.
- Helps keep voltage levels constant for utility, commercial and industrial customers.
- Actively monitors grid conditions and responds dynamically.

Toronto Hydro wanted the end product to blend in with the community and didn't want the storage unit to look different from the green boxes already commonplace in neighbourhoods. eCamion's modular CES units are designed to blend with the urban landscape of the community

Temperature plays a significant role in PV power production, according to Enphase Energy. As a general rule very 1°C increase in cell temperature will result in a 0.5% decrease in power. Clear cold weather is ideal for PV output. Here a 2.35kWh solar panel installation in Toronto.

put into actual grid applications that would prove commercially viable.

"We realized that what CES units existed were all demonstration installations, most of them shipping container-sized things that, despite their huge footprints, still lacked capacity to make any significant impact," says Pizzurro. "What we wanted to do was build a CES system large enough to support a residential street in the event of an outage — as well as facilitate enough system flexibility to offer utilities new options in meeting pressing needs."

To do that successfully meant executing a calculated change of approach, says Hari Subramaniam, who became eCamion's new chief executive in the spring of 2013.

"We knew that to be successful, we'd have to start with a specific customer need, and then work backward from that to design a product that is desirable to other utilities, that is viable in the market. We needed to understand what is possible with the technology, and create in effect, a reverse innovation."

eCamion soon realized that building a battery would be just the first step of many, and that they couldn't take steps alone. "Making batteries is what battery manufacturers know," says Pizzurro. "What they don't always understand is that someone has to integrate those batteries together to make sure they connect properly with the grid."

By early 2010 his company started seeking suitable partners that could produce the battery chemistry they were looking for, and the power electronics and interface that would make it all work.

Most importantly, they needed an electricity utility interested in CES.

And in Toronto Hydro, they found the utility they needed.

In 2006, Toronto Hydro, Canada's largest municipal electrical utility, began to modernize its grid with the installation of smart meters. Since then, it has been exploring the benefits of new technologies including transformer monitors, power line monitors and automated switches.

"We are a distribution company and our priority is to deliver electricity as reliably, cheaply and safely as we can to our customers," says Richard Ford, Toronto Hydro's director of grid solutions engineering. "As we work to rebuild our aging grid, we have to modernize some of our equipment, build a technological foundation that

Larry Dickerman: "One day a fellow who worked in our office on this project came in said to us, what are we going to call this? So we came up with Community Energy Storage, CES, and it's stuck."

is flexible enough to meet demands we can't even envision now.

"Here in Toronto we have issues with aging distribution equipment, and we need to catch up on refurbishment," he says. "But we're also conscious of the fact that if we just replace like with like — in other words equipment that's 20 to 30 years older — then we will have missed an opportunity."

Ford's team decided there were a number of areas on the grid where CES could be of use — if they could find the right format. Ford knew early on they would need a different standard sized unit designed to render a large amount of energy from a smaller physical footprint.

"Utilities are conservative and rightly so, given they're responsible for spending other people's money," says Ford. "We had to be sure we were making the right decisions for our particular situation." Choosing the right size of battery is an important step. "We're more interested in doing something at the neighbourhood level," says Ford about the pilot.

After researching the technology available, Ford's team decided one way to execute the concept they envisioned was with energy-dense lithium-ion batteries.

So when eCamion approached the utility with its CES plan, Toronto Hydro was already open to working together.

Also ready was the third member of the consortium: a group of researchers at the Centre of Applied Power Electronics (CAPE) at the University of Toronto.

The team, headed by Reza Iravani, the centre's director, had already been working on controls and system integration of renewable energy resources at high power levels for some time when eCamion approached them with a unique way of funding a CES project to test its viability in Toronto.

"We had been designing a controller to augment the integration of a battery system with a wind farm," says Iravani. "Though we had not worked with CES before, we had designed control algorithms, effectively a command centre, to specification, and that's what was needed for the community energy storage project: a brain."

What drew Iravani's team to the project was eCamion's technology which consisted of an advanced modular battery new to this kind of application, and a battery management system (BMS) designed to allow an unusually broad software interface capacity with different communications and software protocols.

It is also designed to work with a control protection and power management software (CPPM), a controller-based algorithm that, in acting as a converter, allows the battery to interact with the grid.

eCamion's proprietary BMS, the brainchild of Leo Canale, eCamion's technical director, was the firm says, a first in its field. At the time, none of the

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available standard BMS — designed specifically to function in electric vehicle and bike applications — were able to do the job they wanted to do.

"The BMS typically found in electric vehicles was close, but still insufficient to accommodate something as large

Inside the box: an array of lithium batteries that can deliver 250kWh of storage

"Utilities are conservative and rightly so, given they're responsible for spending other people's money. We had to be sure we were making the right decisions for our particular situation" — Richard Ford, Toronto Hydro

Power and energy	
Energy storage capacity	250kWh
Rated continuous power	500kW
AC grid-Tie Voltage	240V, 480V, 600V
DC Bus	600V
Ramp rate	< 5 seconds to rated power
Grid frequency	50, 60Hz
Inverter options	Configurable: four-quadrant, low voltage ridethrough, islanded operation, enclosure, etc.
Roundtrip Efficiency	>90% at rated power

Battery system	
Chemistry	Lithium Polymer, Nickel Manganese Cobalt (NMC)
Nominal capacity	69,120Ah
Cycle Life	Up to 5,000 at 80% DOD
Self-discharge rate	<1% per month at 20°C
Battery management system	Advanced smart BMS included

Mechanical	
Enclosure rating	NEMA 4
Dimensions	3019mm x 2408mm x1686mm
Weight	7,000 kg
Thermal management	Active heating and cooling
Operating temperature	-20°C to 60°C
Storage temperature	-20°C to 60°C

Communications and control	
Grid control	DNP3/IEC 61850 over SCADA
Distributed intelligence	Automated P and Q setpoint control via Control, Protection, and Power Management (CPPM) module
External I/O	Analog and digital available
Data logging	Cellular to onboard database

as what we knew we had to create," says Canale. "Vehicles have 40kW-50kW systems, whereas a CES unit is 500kW. Also, we couldn't just buy a vehicle BMS, it's proprietary technology that's exclusive to the manufacturer. We had to develop our own. My job was to devise a BMS that would manage the batteries but with much greater capacity and be functional with multiple inverters."

"Our task upon joining the consortium was to integrate the power electronics into a fully functioning system that would operate with the highest degree of reliability," says Iravani. "To do that the batteries, which are not directly connected, have to be worked in through the power converter. That's the crucial link."

The University of Toronto's team designed smart grid algorithms and integrated them into a supervisory control system that records data from the grid and communicates it to the utility, the BMS, and the power converters.

The completed system is the first grid scale energy storage unit within a small pad-mounted footprint. Its modular design structure, customizable to accommodate additional operational functions (an inverter and an interface with the utility), can provide fast, medium and slow control for Energy Management System functions, without changing the algorithms. It can also be customized to use off-the-shelf hardware.

The energy storage unit, which is connected to the grid, processes incoming signals that command it to perform certain functions, depending upon grid status. If the grid is overloaded, it will signal the battery to discharge energy, and thus shave peak demand.

"Toronto Hydro has full control over the entire battery and system," says Ford. "We can change the settings, disconnect, or operate it any way we wish, all remotely. It also tells us what any given problem actually is, so that we can send out a crew with the right expertise to fix it.

"This level of smart control is important because it can help reduce man hours in the field and thus saves costs."

Testing times

Since the first unit was installed in February 2013, Toronto Hydro has run the system through extensive test cycles. Toronto Hydro is spacing the projects out over three years. "We wanted to be able to concentrate on

each one in turn," says Ford. "We wanted to learn the benefits of the first unit so we could build what we learned into the second. So it is a consciously phased approach. The first unit is constructed, installed, and now in use."

So far, Ford says, they've learnt a lot — and positively— everything is performing well, either meeting or exceeding expectations. "It's all about demonstrating whether we can use these units, and now we know that we can," he says.

"Pilot projects like these are important so that we test out new technologies and can fully understand their inherent benefits before we commit. That said, we are still gathering the data to see whether or not we have a viable business case."

To do that, the consortium requires a range of communities to test the technology. eCamion and Toronto Hydro, are already seeking out different applications for the second and third installations. The list of possibilities includes spaces such as apartment blocks, commercial buildings, and even hospitals where there is a need for more secure energy supply.

"The main thing is to gain experience with these units in real operation and integration, so that we can tailor the battery and the application for a particular market," says Subramaniam. "A number of utilities are monitoring this project. Many would have a need for this in rural areas, which present very different needs than urban settings moving us into microgrids with our advanced controller."

DETERMINING A VALUE PROPOSITION

CES can create value for the grid. But the question facing both the utilities and the policy makers is by how much?

To date, most demonstration and test CES projects have focused on deployment of hardware and operating systems to prove functionality and potential benefit to utilities. Yes, battery prices are coming down, performance is ramping up, systems are easier to install and integrate with the grid. But how much in cost savings operators might realize through using CES technology cannot be determined for some time.

"In terms of the commercial deployment of new technologies, my sense is that it is still too early to tell," says Richard Ford, Toronto Hydro's director of grid solutions engineering. "There are a few promising technologies now being demonstrated. We're proud to be part of that early push. But in terms of batteries, there is still a need for prices to fall."

"And of course it is quite possible that some of the attributes that they assumed would make for a strong business case, could well turn out to be less than anticipated," says Carmine Pizzurro, the founder of eCamion.

"We still need to find better ways to quickly, inexpensively, reliably and repeatedly deploy energy storage into a utility ecosystem that will create technical and business value with it," Subramaniam says.

"The only good way to get a good view of the value of such benefits is to do it for real. A clear understanding of how this technology can be monetized will give manufacturers a solid understanding of the business."

eCamion's chief executive Hari Subramaniam nevertheless reckons that CES will soon be part of utilities' budgeting. "US DOE and Sandia National Laboratories have been working on value proposition modelling for public use, the industry is utilizing that expertise to build their own models for specific customers. The Toronto Hydro project is important from a data-gathering perspective to qualify its benefits. "What we learn from this, I believe, will move Intelligent Community Energy Storage to the forefront of Utilities capital expenditure"

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250KWH COMMUNITY ENERGY STORAGE SYSTEM

LINCHPIN OF THE NEW ENERGY ERA

eCAMION is a leading turnkey solution provider for Community Energy Storage. eCAMION specializes in the integration of battery solutions with intelligent advanced grid controls whitch interface to a Utility's control room. The intelligent controls operate seamlessly with building management systems, onsite generation, and the modern smart grid. We provide modular, flexible energy storage, which improves reliability by optimizing new battery chemistries as well as repurposed vehicle batteries. We protect critical loads and operations during electricity disruptions (e.g. outages). The applications include:

Energy efficiency – power factor correction, and reduced losses
Time of use – peak shaving and valley filling based on TOU periods
Demand management – shaving off peak demands
Frequency regulation – Volt / VAR optimization, grid stability and power quality
Renewable integration – facilitate the connection of clean energy into building operations, including voltage regulation, buffering of intermittency, and ensuring green electricity is locally consumed
Electric vehicle charging – supporting fast charging of electric vehicles without requiring facility or utility capacity upgrades
Facilities expansion – supporting load growth in local facility without requiring capacity upgrade from the utility company
Future applications – Demand Response, backup power and microgrids

eCAMION Community Energy Storage system advantages:

- ✓ Innovative designs including patent pending module design and cooling
- ✓ Flexible and scalable module design from 75kWh to 250kWh
- ✓ Grid support for up to 150 homes
- ✓ Smart Battery Management System (BMS)
- ✓ Intelligent controls with utility grid integration and coordination that automate the CES' operations based on local utility grid conditions.

Advantages of eCamion's Proprietary Battery Management System (BMS):

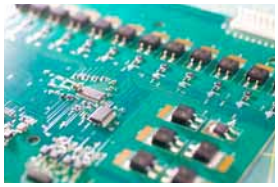
- ✓ Master controller monitors the system and has appropriate safety redundancies
- ✓ Each battery module is analyzed, monitored and optimized for;
  - State of Charge (SOC)
  - Voltage
  - Current
  - Cell Capacity
  - Temperature
  - Efficiency
- ✓ Cell balancing
- ✓ Fast switching between charge/discharge
- ✓ Protections against under/over-voltage, temperature and over currents
- ✓ Safety protocols with safety alarms and shutdowns
- ✓ Web based and Ethernet ready
- ✓ Designed and configured to work smoothly with Control, Protection Power Management units

Advantages of eCamion's Control, Protection Power Management (CPPM):

- ✓ Modular unit within CES control box that has built in intelligence to manage Energy Storage system, Inverter system and grid-controls
- ✓ Unified hardware-software architecture that encompasses strategies and the corresponding intelligence to manage Community Energy Storage (CES) unit.
- ✓ The CPPM selects and activates a new CES mode of operation by means of its software intelligence and logics, based on real time commands from utility control room, from a customers remote signal or on site commands
- ✓ In conjunction with Utility requirements selects and invokes a CES mode of operation based on the battery State Of Charge (SOC) and distribution grid immediate and longer-term (few hours) needs
- ✓ The design structure is easily customizable and can accommodate additional functions in terms of operation of the Inverter and interface with the utility
- ✓ Can provide fast, medium and slow control/EMS functions without changing its algorithms
- ✓ Can be customized with off-the-shelf hardware platform depending on the customers requirements
- ✓ Has operational clearly defined modes at different speed (slow to fast) depending on the grid and the type of Inverter.

Padmount units providing the "perfect fit" into utility infrastructure, providing load leveling, renewable integration, electric vehicle charging, backup power, and regulation services

Modular, flexible, and scalable battery storage modules supporting a wide variety of applications



Advanced BMS and intelligent controls for seamless utility smart grid integration

SYSTEM SPECIFICATIONS:

Power and Energy	
Energy storage capacity	250kWh
Rated Continuous Power	500kW
AC Grid-Tie Voltage	240V, 480V, 600V
DC Bus	600V
Ramp Rate	< 5 seconds to rated power
Grid Frequency	50, 60Hz
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