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Community Energy Storage Report

January 14, 2011

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Dominion Power

Duke Energy

NCEMC

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Executive Summary

During 2010, Advanced Energy engineers attended the Electricity Storage Association's (ESA) annual meeting in Charlotte, N.C., conducted telephone interviews as well as internet research to learn about current and near-term community and residential energy storage technology. This report provides a summary of Advanced Energy's findings.

Several utilities including American Electric Power (AEP), Detroit Edison (DTE) and Sacramento Municipal Utility District (SMUD) have community energy storage demonstration projects underway. A brief description of each project is included in this report. In response to utility demand for distributed electricity storage systems, several manufacturers have developed CES units. As such, AEP and Electric Power Research Institute (EPRI), with input by utilities and other companies, have developed a specification for Community Energy Storage (CES) systems. A brief description of each of their projects is also included here.

Background and Project Scope Review

Representatives from Advanced Energy, Dominion Power, Duke Energy, North Carolina Electric Membership Corporation (NCEMC) and Progress Energy met on February 18, 2010 to discuss items of interest to test at the Energy Technology Testing Center (ETTC) during 2010. A list was generated and votes were taken from all interested parties to determine the top priorities for testing. One top item of interest was having ETTC investigate commercially available CES technology. The other items evaluated were:

- GE GeoSpring hybrid heat pump water heater;
- Home energy monitors; and
- Future residential load characteristics.

The Residential Energy Storage project focused on commercially available residential and community-scale electrical energy storage systems. Advanced Energy engineers conducted telephone interviews, internet research and attended the May 2010 Electricity Storage Association's (ESA) annual meeting in Charlotte, N.C. to learn about current and near-term community and residential-scale energy storage technology.

Electricity Storage Association Annual Meeting

The Electricity Storage Association (ESA) is a trade association established to foster development and commercialization of energy storage technologies. Their mission is "to promote the development and commercialization of competitive and reliable energy storage delivery systems for use by electricity suppliers and their customers." The goals of the ESA are to:

- Promote the commercial application of energy storage technologies as solutions to power and energy problems;
- Coordinate and attract international interest and involvement in energy storage; and
- Provide a forum for technical and commercial information exchange between suppliers, customers and researchers.

ESA 20th Annual Meeting

The ESA held its 20th annual meeting on May 4 - 7, 2010 in Charlotte, NC. The meeting was hosted by Duke Energy and supported by United States Department of Energy (DOE) and Sandia National Laboratories. There were 350 attendees registered for the meeting and two engineers from Advanced Energy attended. There was an optional workshop on The Energy Storage Value Proposition on May 4. The opening session, reception and technology showcase with 22 exhibitors was held the evening of May 4. During the meeting, there were 42 presentations on current and future electric energy storage technologies for residential and utility grid-scale applications. A tour of the Parker SSD Drives facility in Charlotte was given on May 7.

Energy Storage Value Propositions

Two of the main applications (value propositions) for electricity storage discussed during the ESA meeting were "arbitrage" and "ancillary services." Arbitrage is the practice of taking advantage of a price difference between two or more markets. For instance, during peak periods, using stored electricity may be more economical than generating additional electricity to meet the demand. Ancillary services are defined by the Federal Energy Regulatory Commission (FERC)[1] as "those services necessary to support the transmission of electric power from seller to purchaser given the obligations of control areas and

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[1] U.S. Federal Energy Regulatory Commission 1995, Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities, Docket RM95-8-000, Washington, DC, March 29, 1995

transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system."

The FERC identifies six ancillary services as:

- Reactive power and voltage control;
- Loss compensation;
- Scheduling and dispatch;
- Load following;
- System protection; and
- Energy imbalance.

Energy Storage Technologies

The main energy storage applications discussed during the ESA annual meeting were grid storage, community energy storage, pumped-hydro storage, compressed air storage and wind and solar energy storage for capacity firming. The energy storage technologies presented on during the meeting included:

- Compressed Air Energy Storage "CAES"
- Flywheel energy storage
- Zinc-Bromine flow batteries
- Ice storage
- Lithium-Ion (Li-Ion) batteries
- Bipolar Lead Acid batteries
- Lead-Carbon batteries
- Super capacitor / battery
- Sodium Nickel batteries
- Sodium-Sulfur (NAS) batteries
- Zinc Air batteries
- Liquid metal batteries
- Renewable power to Substitute Natural Gas

Of these energy storage technologies, those discussed for CES applications included Li-Ion batteries and Zinc-Bromine flow batteries.

Community Energy Storage Technologies

Community Energy Storage (CES) is electricity storage located at the edge of the electric utility grid closest to the end user. CES systems bundle batteries, battery management systems, inverters, controls and communications into one compact enclosure. CES units are located in outdoor, pad-mounted enclosures between the electric utility transformer and the meters serving two to four residences, with integrated power monitoring and dispatch controls operated by the utility company. CES systems allow for battery charging during off-peak hours when energy prices are low and dispatching during on-peak times when the cost of energy is high. The CES allows homes to operate independent of the local utility grid for a few hours during power outages or during peak demand periods. CES systems usually have a power rating of 25 to 30 kW and an energy storage capacity of 25 to 75 kWh. The batteries in CES systems are usually plug-in hybrid electric vehicle type using Lithium-Ion technology.

Residential Energy Storage Technologies

Residential Energy Storage (RES) units are a special case of the CES systems that serve only one residence. RES systems bundle batteries, battery management systems, inverters, controls and communications into one compact home energy appliance. The systems are usually located on the customer side of the electric utility meter and can be integrated with power monitoring and dispatch software, allowing charging during off-peak hours when energy prices are low and dispatching during on-peak times when the cost of energy is high. Charging and dispatching operation can be controlled by the home owner, the utility or a third party service provider. RES systems usually have a power rating of 5 to 10 kW and an energy storage capacity of 10 to 20 kWh. The batteries in RES systems are usually sealed Lead Acid or Lithium-Ion. RES systems with Zinc-Bromine flow batteries are expected to be commercially available within the next year or two.

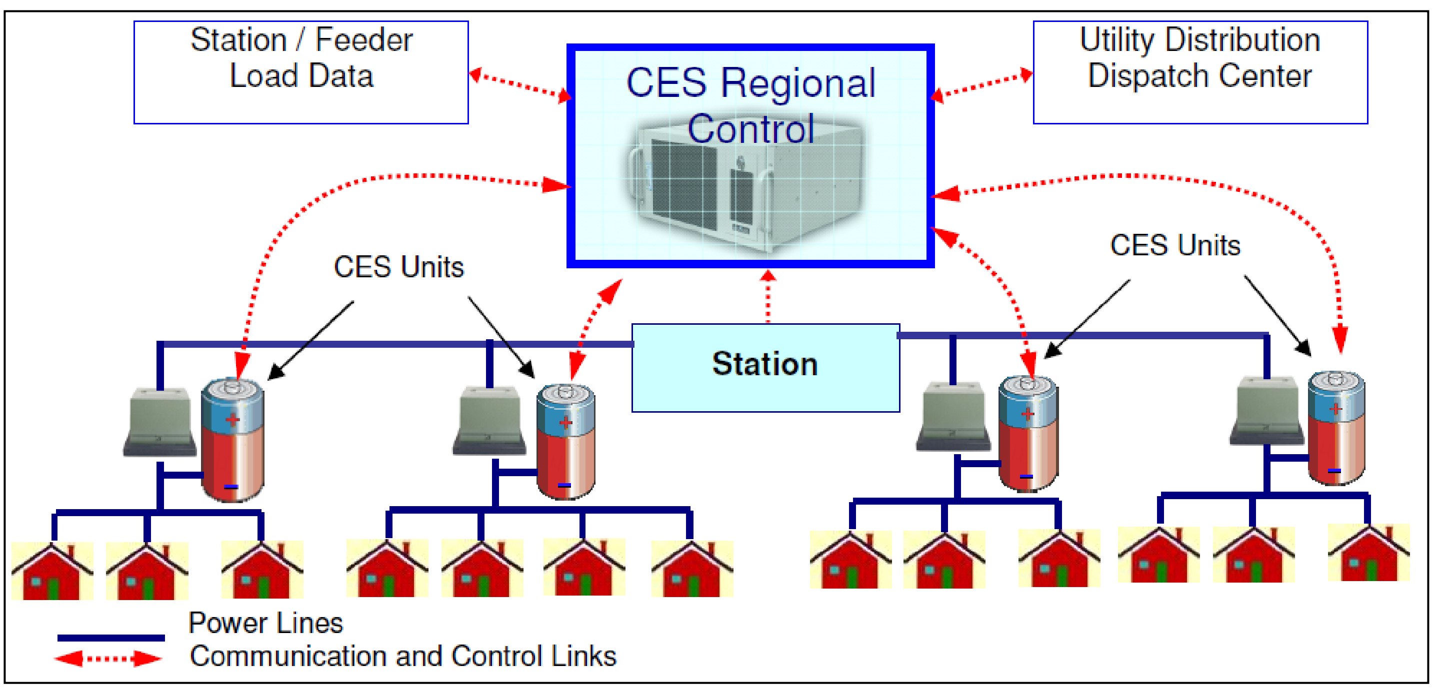
American Electric Power CES Specifications

American Electric Power (AEP) and Electric Power Research Institute (EPRI), with input from utilities and other companies, developed a specification for CES systems. The specification is available for free to utilities, vendors and other interested parties and can be found at AEP's website (www.aeptechcenter.com/CES). The following four paragraphs and two figures describing CES are taken directly from AEP's Revision 2.2 of the Functional Specification for Community Energy Storage Unit.

Community Energy Storage (CES) consists of multiple small battery-based energy storage units connected to the utility transformers' 240/120 V secondary and controlled from a common remote control. Initially the individual CES Units will be pad-mounted and typically be deployed in Underground Residential Distribution (URD) settings adjacent to a single phase pad mount transformer. A large number of these small storage units will be aggregated regionally and controlled as a fleet (see Figure 1).

The individual CES Units will have controls to manage their individual charge and discharge activity in response to regional needs at the feeder, station, or system level. The regional needs will be managed by a CES Control Hub or by integration into another control platform, herein referred to as an Integration Platform. If used, the CES Hub will be deployed as hardware and software typically installed at the station for the feeder(s) on which its fleet of CES Units are installed. A utility may elect to implement the same control functionality in an Integration Platform which has broader application, possibly including other distributed resources. The Integration Platform would not require the hardware on which the CES Hub will implement this regional control functionality.

Figure 1: Communication & Control Layout for CES – from Revision 2.2 of Functional Specification For Community Energy Storage (CES) Unit



CES will provide capacity, efficiency, and reliability benefits through the following key functions:

Grid functions:

1) Serve as a load leveling, peak shaving device at the station level

2) Serve as a power factor correction device at the station level (VAR support)

3) Be available for ancillary services through further aggregation at the grid level

Local functions:

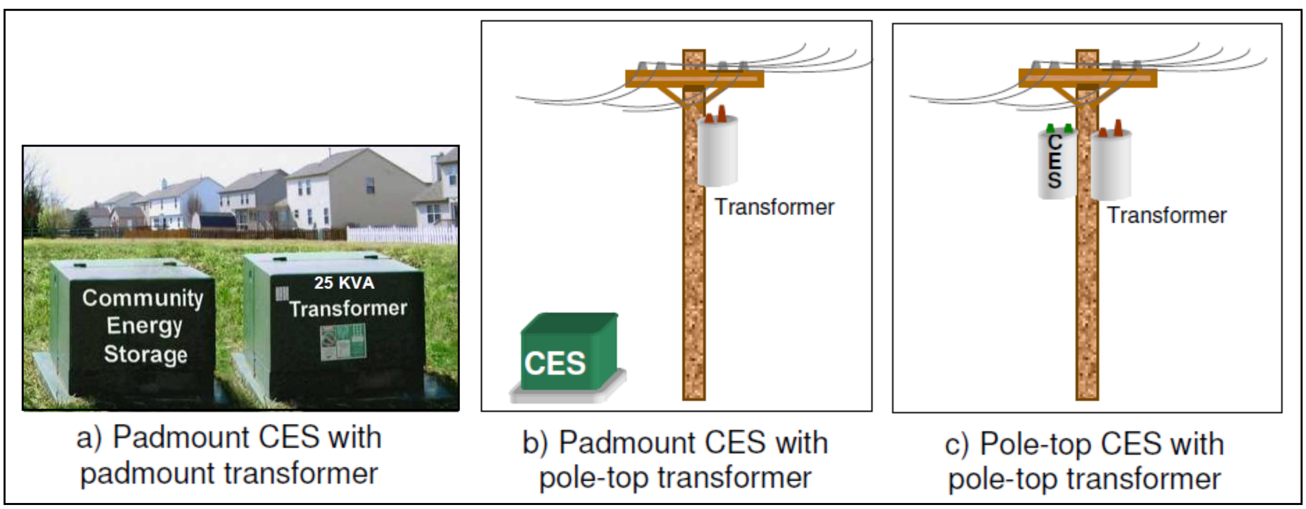
4) Serve as backup power for the houses connected locally

5) Serve as local voltage control

6) Provide efficient, convenient integration with renewable resources

Initially the individual CES Units will be pad-mounted and typically be deployed in Underground Residential Distribution (URD) settings adjacent to a single phase pad mount transformer. Alternatively, the CES Unit may be installed at the base of a secondary riser pole for use on overhead facilities. A future specification may require a pole mounted version. Figure 2 shows the installation configurations that are envisioned.

Figure 2: Possible combinations of CES with residential transformers - from Revision 2.2 of Functional Specification For Community Energy Storage (CES) Unit

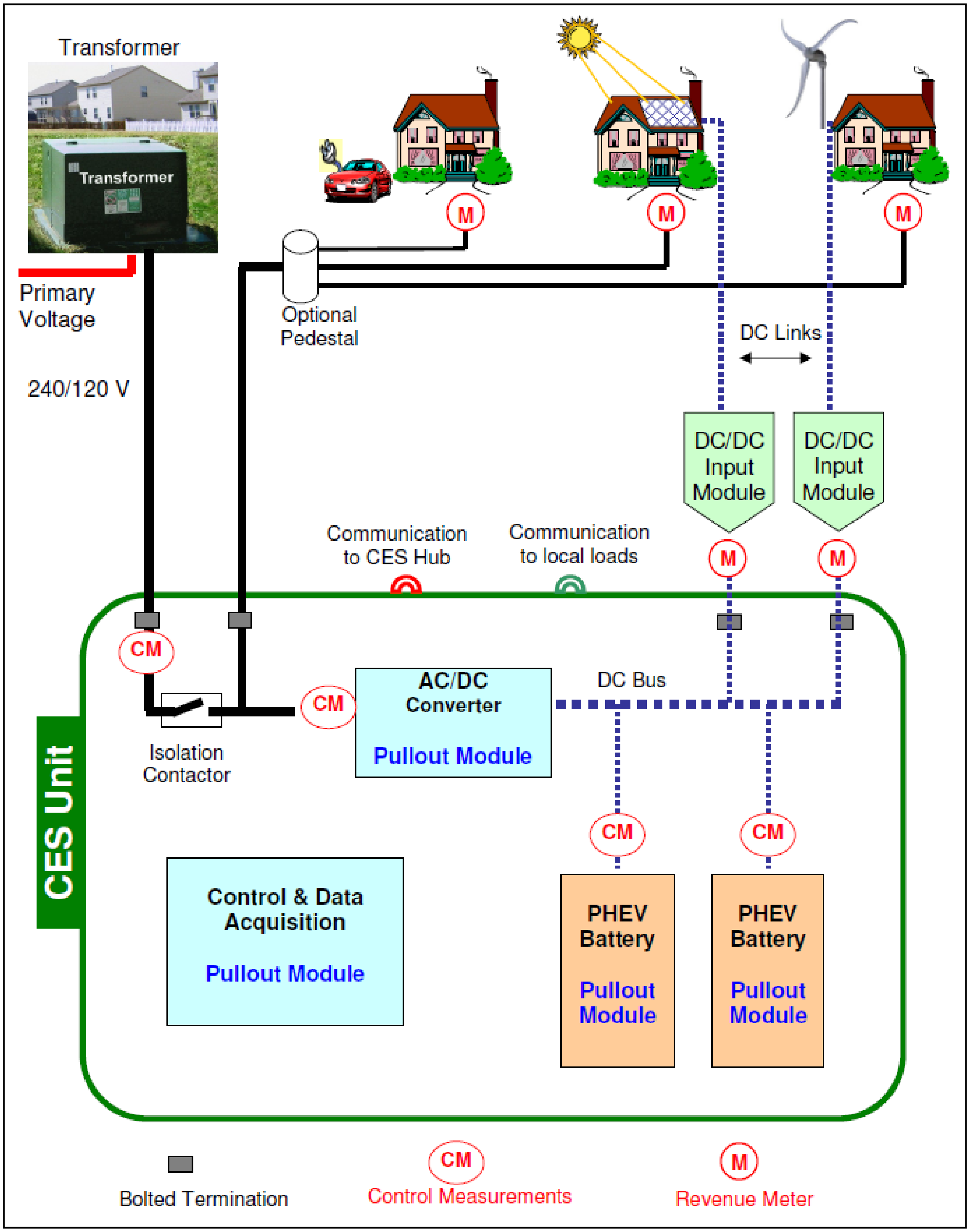


The Functional Specification For Community Energy Storage (CES) Unit is a large document but some of the basic specifications for the CES unit are shown in Table 1. The layout of a CES installation serving three residences, along with its main components, is shown in Figure 3. Note that plug-in hybrid electric vehicle (PHEV) batteries are specified for CES units in Table 1 and Figure 3. PHEV Lithium-Ion batteries have characteristics that make them a good fit for CES. These include high energy density and high charge/discharge rates. Also, the rapid growth of the electric vehicle market is helping drive down the cost of Lithium-Ion batteries. CES units are also being considered as an application for secondary-use electric vehicle (EV) batteries.

Table 1

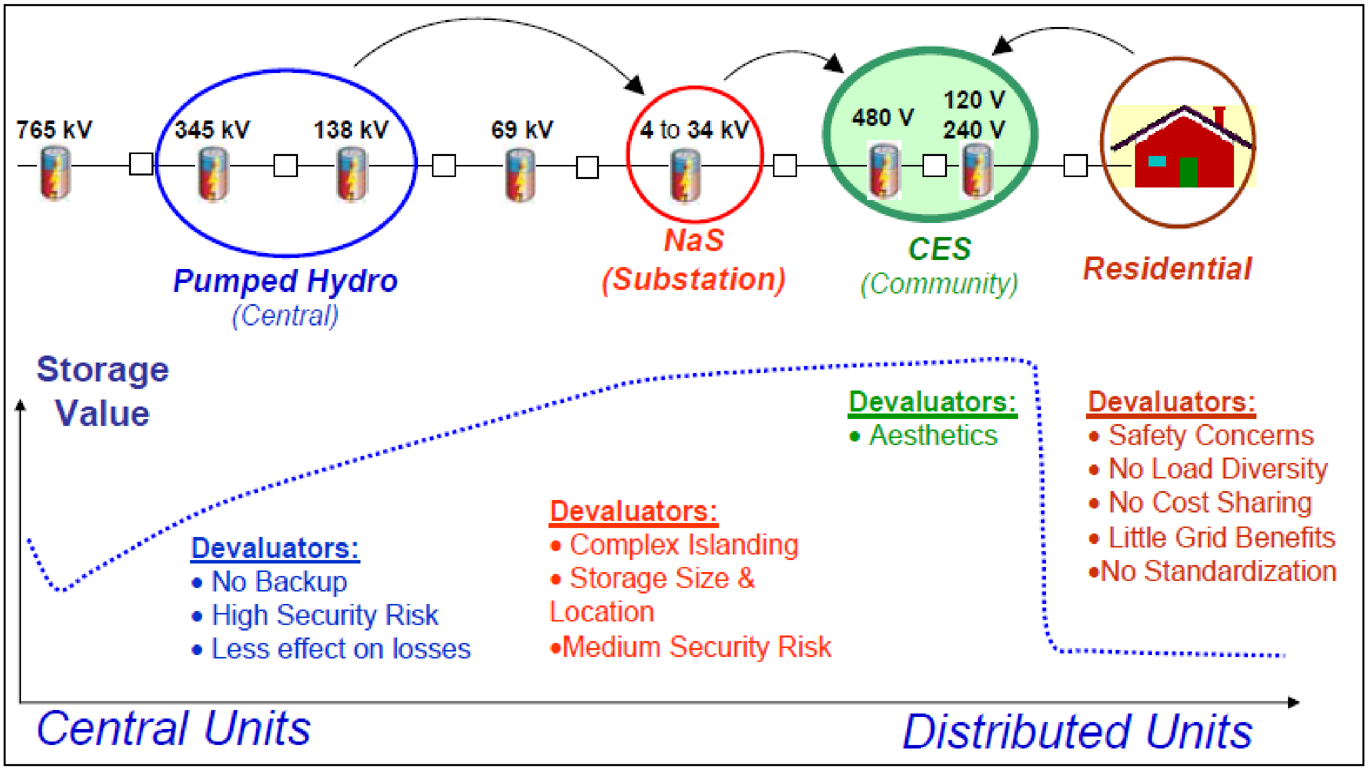
AEP CES Unit Basic Specifications	
Key Parameter	Value
Power	25 kW
Energy	25 to 75 kWh
Voltage - Secondary	240 / 120V
Battery - PHEV	Li-Ion
Round Trip AC Energy Efficiency	>85%

Figure 3: Layout of CES Installation and Its Main Components - from Revision 2.2 of Functional Specification For Community Energy Storage (CES) Unit



As shown in Figure 4, AEP considers electricity storage placed at the edge of the grid to be the most valuable. CES units are located at the edge of the grid between the transformer and electrical meters serving multiple homes. The devaluators shown in Figure 4 describe why electricity storage at the community level is more valuable than at the residential level.

Figure 4: Value of Electricity Storage – From AEP gridSMART Presentation - March 3, 1010



AEP Ohio gridSMART CES Demonstration Project

AEP Ohio is currently conducting a CES demonstration project in Columbus, Ohio, which is part of the larger federally funded AEP Ohio gridSMART Demonstration Project. The CES project will install 80 S&C 25-kW/25-kWh CES units along a distribution feeder serving 1,742 customers with a peak load of 6.3 MVA. The CES units will cover approximately 20% of customers on this circuit. The aggregated capacity of these 80 units is 2 MW and 2 MWh. All 80 units will be controlled by one CES control hub, acting as a virtual substation battery. The prototype CES units were under construction in June 2010. The first 20 units are scheduled to be installed in April 2011. The remaining 60 units are scheduled to be installed in October 2011. Monitoring of these systems will continue until December 2013.

S&C CES Unit

S&C Electric Company developed the CES unit for the AEP Ohio gridSMART Demonstration Project. The unit was developed based on the AEP Functional Specification for CES units. The unit uses Lithium-Ion batteries provided by International Battery and has a 25 kW power rating with 28 kWh of energy storage. The energy storage system will be installed below ground level in a vault beneath the power electronics enclosure. The vault will be filled with oil to reduce corrosion from moisture and water intrusion. Figures 5 and 6 show the unit under development.

Figure 5: Batteries Located in Below-Grade Vault

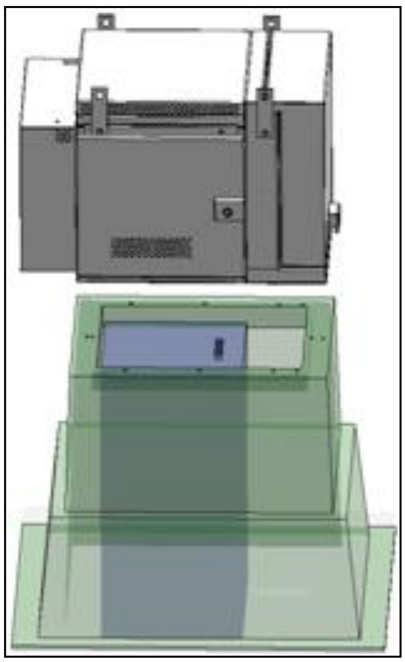


Figure 6: S&C 25 kW CES Unit Under Development

International Battery CES Unit

International Battery is developing a CES unit for EPRI similar to the S&C unit developed for the AEP gridSMART project. It has a 25 kW power rating and is available with a 50 kWh Lithium-Ion battery. The power electronics are mounted in one side of the pad-mounted enclosure and the batteries are mounted in the other side. International Battery is expecting to begin delivering this product in second quarter 2011.

Figure 7: Power Electronics Side of International Battery CES Unit

Figure 8: Battery Side of International Battery CES Unit

Detroit Edison CES Project

Detroit Edison (DTE) is conducting a CES demonstration as part of its Advanced Implementation of A123's Community Energy Storage Systems for Grid Support project. The project is funded in part by the Energy Storage Systems Program of the U.S. Department of Energy. DTE's CES project will install twenty 25 kW / 50 kWh CES units along a residential distribution feeder in Northville near Detroit, Mich. The aggregated capacity of these 20 units will be 500 kW and 1 MWh. The 20 units will be controlled by DTE's Distributed Resources System Operations Center. A123 Systems will be providing CES units to the project comprised of their own batteries along with S&C's inverter and power electronics enclosure. The CES units are expected to be installed and tested between mid-2011 and mid-2013. A second phase of testing incorporating used plug-in electric vehicle (PEV) batteries, provided by Chrysler, will be conducted between mid-2013 and mid-2014.

A123's Systems CES Unit

The A123 Systems CES unit being used in the DTE project has an above-ground 25 kW inverter and power electronics enclosure provided by S&C Electric Company and a below-ground 50 kWh A123 Lithium-Ion battery system as shown in Figures 9 to 11[2]. The A123 battery pack weighs 1,250 pounds and is enclosed in a liquid-tight container installed inside a below–ground fiberglass vault. The A123 Systems' CES design leverages the

[2] From DTE's Nov. 3, 2010 presentation on the Advanced Implementation of A123's Community Energy Storage Systems project by Hawk Asgeirsson. http://www.sandia.gov/ess/docs/pr_conferences/2010/hawk_dte.pdf

independent work done by S&C for other projects such as the AEP Ohio gridSMART project.

Figure 9: A123 Systems CES Unit

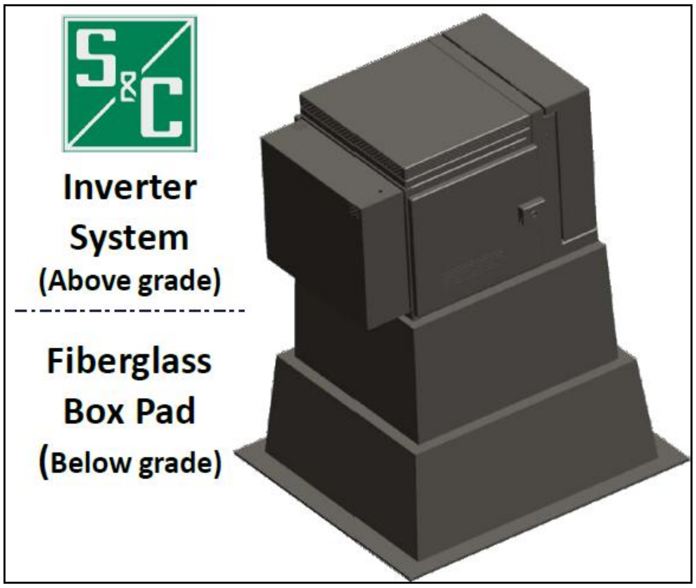


Figure 10: A123 Systems Lithium-Ion Battery System

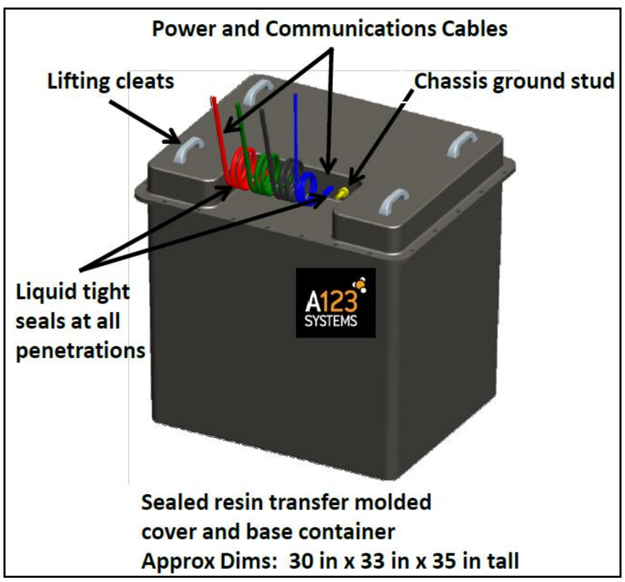
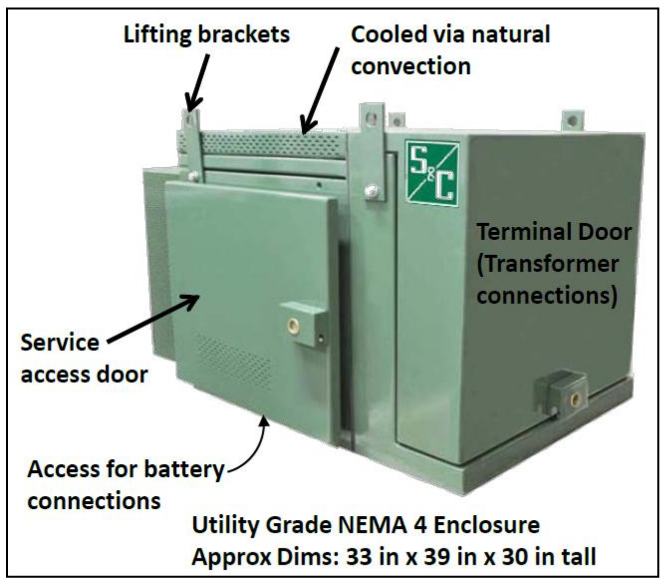


Figure 11: S&C Inverter System



SMUD Solar Smart RES/CES Project

In order to evaluate how energy storage can enhance the value of solar photovoltaic (PV) and wind generation in a smart grid environment, Sacramento Municipal Utility District (SMUD) has undertaken the SMUD PV & Smart Grid Pilot at Anatolia project. The project is funded by the U.S. Department of Energy and the project partners including SMUD, National Renewable Energy Laboratory (NREL), GridPoint, SunPower and Navigant Consulting. In this project, 55 to 65 homes in the Anatolia neighborhood in Rancho Cordova, Calif. will be studied. Each of these homes has an existing 2 kW solar PV system installed. Residential energy storage (RES) systems will be installed on 15 of the homes known as the RES group. Three CES units serving five to nine homes each will be installed for 15 to 25 of the homes known as the CES group. The remaining 25 homes will serve as the control group.

The strategic objectives and key research questions of the SMUD PV & Smart Grid Pilot at Anatolia project are[3]:

- Understand how the integration of energy storage could enhance the value of distributed PV resources within the community;
- Determine if the addition of energy storage could add value for the utility;
- Determine how to leverage SMUD's AMI investment to manage a distributed PV/energy storage resource; and
- Determine if capacity firming and advanced pricing signals will influence the energy usage behaviors of customers.

The RES group energy storage units will be installed indoors on the customer side of the electric meter. The SilentPower OnDemand RES appliance shown in Figure 12 will be used for these homes. It has a power rating of 10 kW and has a Saft 9 kWh Lithium-Ion battery pack.

The CES group energy storage units will be connected to pad-mount transformers on distribution feeders and will be sized to work with the group of homes fed by each

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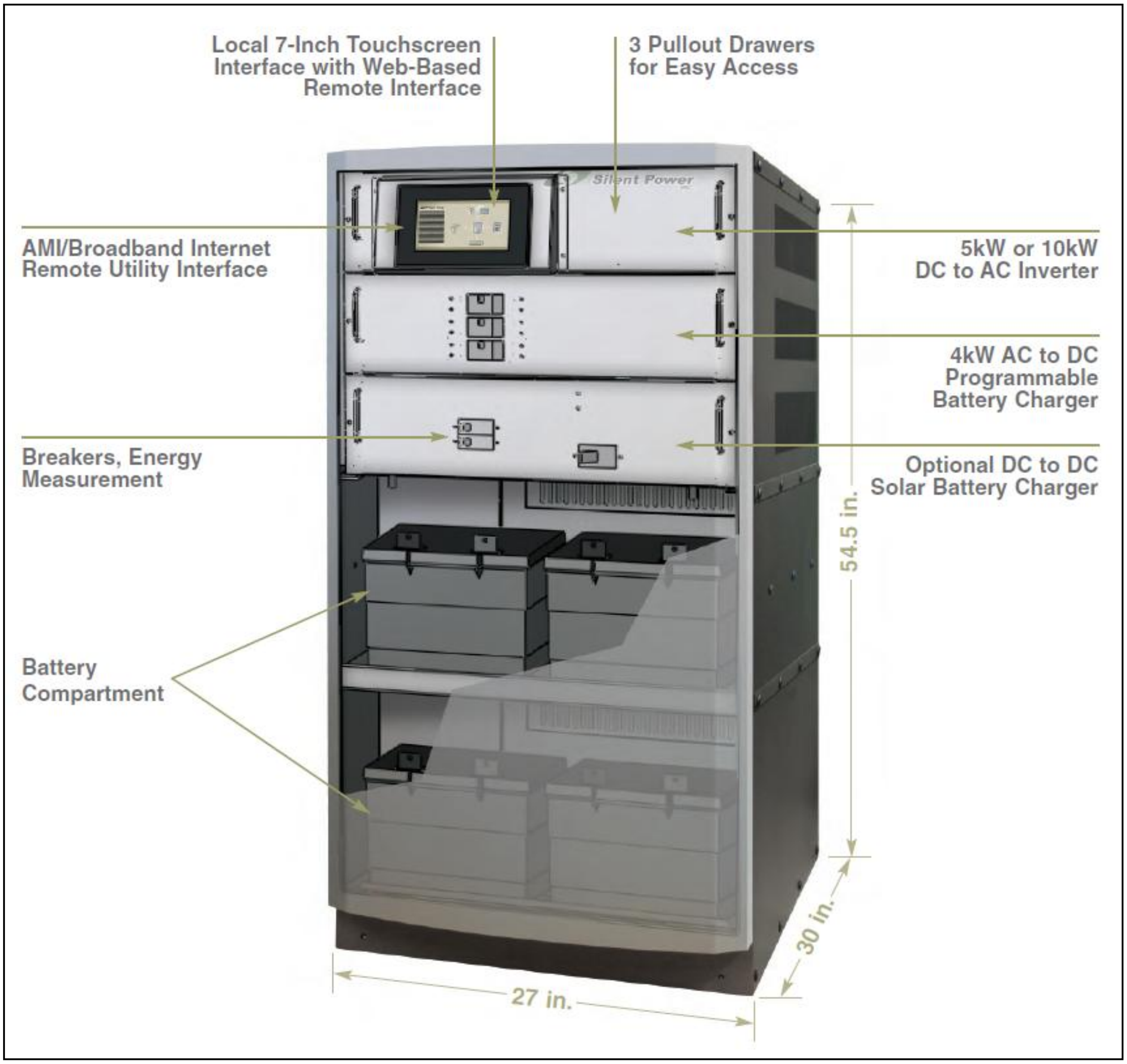
[3] From SMUD's June 24, 2010 presentation How Can Energy Storage Enhance Value of PV and Wind in a Smart Grid Environment by Mark Rawson. http://www.nwppa.org/web/presentations/2010_Power_Supply_Workshop/NWPPA%20 SMUD_presentation_Mark%20Rawson.pdf

transformer. The VPT-ES CES system to be used will have a 30 kW power rating and will incorporate a Saft 30 kWh Lithium-Ion Battery pack.

Figure 12: Silent Power OnDemand 5 or 10 kW / 9 or 12 kWh RES Unit



RedFlow RES Units

RedFlow is an Australian company that develops and sells Zinc-Bromine flow battery energy storage systems for the electric utility and renewable energy markets. Their products are designed for peak-load reduction in Smart Grid applications as well as enhancement of intermittent renewable solar PV energy in on-grid and off-grid applications. RedFlow produces kW scale battery systems with integrated control systems and inverters for outdoor installation at homes and businesses. RedFlow's current systems offer 5 kW of power and 10 to 30 kWh of energy storage (enough to power a typical household for two to 24 hours). RedFlow has two product ranges. RedFlow's LA system is an integrated electricity storage system using conventional lead acid (LA) batteries. This allows RedFlow to prove its control and communication systems and the palletized design in the field at this early stage of product availability. RedFlow's ZB system is an integrated electricity storage system using RedFlow's high capacity Zinc-Bromine (ZB) battery system. ZB systems are undergoing field trials in Australia ahead of a general market release.

Zinc-Bromine flow batteries use liquid electrolyte that is pumped through the system. The electrolyte is a solution of Zinc Bromide and water is stored in two tanks. When the battery is charged or discharged, the solutions are pumped through a reactor stack and back into the tanks. One tank is used to store the electrolyte for the positive electrode reactions and the other tank is for the negative. The Zinc-Bromine battery is essentially an electroplating machine. During charging, Zinc is electroplated onto conductive electrodes, while at the same time Bromine is formed. On discharge the reverse process occurs. The metallic Zinc plated on the negative electrodes dissolves in the electrolyte and is available to be plated again at the next charge cycle. In the fully discharged state, it can be left indefinitely for later charge.

Some of the advantageous features of the Zinc-Bromine batteries are:

- High energy density relative to lead-acid batteries;
- 100% depth of discharge capability on a daily basis; and
- High cycle life of >2,000 cycles at 100% depth of discharge before servicing to increase life.

Additionally, unlike lead-acid batteries Zinc-Bromine batteries are non-perishable

RedFlow makes the following additional claims about their ZB product line.

Key Competitive Advantages

- Much lower cost – targeting a manufactured cost of 40% of conventional high performance lead acid batteries
- Designed for daily 100% depth of discharge

Technical Features

- Developed specifically for high energy throughput & low cost
- Compact and light weight. Primarily manufactured from plastic
- Typically 4 hour charge, 4 hour discharge

- Target life of more than 3000 cycles
- Repairable and fully recyclable
- Minimal performance deterioration over time – electrolyte does not wear out and is fully reusable
- Safe and environmentally friendly product – no toxic heavy medals, recyclable, ambient operating temperature
- Weight of only 220 kG for 10 kWh module – high energy density
- Designed to be modular – 5 kW, 10 kWh unit building block

The RedFlow Zinc-Bromine battery module (ZBM), showing in Figure 13, has a 5kW power rating and 10 kWh energy storage capacity. Multiple ZBMs can be linked together for higher power and higher capacity requirements. Three ZBMs are used in parallel to provide 30 kWh of storage capacity in the RedFlow 5 unit shown in Figure 14.

Figure 13: RedFlow 5 kW/10 kWh ZBM Zinc-Bromine Battery Module

Figure 14: RedFlow 5 RES unit – 5 kW/30 kWh