

Grid Storage and the Electrification of Transportation

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What? They're charging during the day!

Everybody's talking about them – electric vehicles and plug-in hybrid electric vehicles, collectively known as plug-in electric vehicles (PEVs). Most forecasts of the impact of PEVs on the grid are based on PEVs starting to charge late in the evening in the family garage and then finishing by early morning. And this will be true for most of the earlier adopters. This new load will be good for the utilities because it will help fill the nighttime valley – leveling the load factor. This new nighttime load can absorb renewable energy from wind farms. This is all good news for the electric power industry, if it's true.



But this may not be completely true, particularly in large cities. Many vehicles may not have access to public or private charging stations in the evening. Some urban PEV

owners may only be able to charge while at work. And a suburban PEV owner may still want to “top the tank” for the trip home while at work or at the shopping center. This is a very significant consideration for a pure electric vehicle which, unlike plug-in hybrid electric vehicle, depends exclusively on stored electricity to get home. For PEVs to really flourish, public charge stations must be ubiquitous. They will need to be on city streets, in parking garages, at airports, at malls, at sports venues, at business parking lots – everywhere!

PEV charging loads could vary significantly during the day at a large “park and charge” facility if the PEV charging sessions are not actively managed. There will be times when all of the charge stations are empty and other times when they will all be occupied and in use and drawing rated power. This could be a problem. Random peaks will set the monthly demand charge for the facility. The facility may have demand response commitments to meet.

The SAE is currently defining a PEV communication capability that will allow a facility Energy Management System (EMS) to communicate with each connected PEV and dynamically coordinate the power demanded by the PEV throughout its charging session. The challenge is to create **intelligent Power and Energy Management (iPEM)** logic for the EMS that can accept an energy transfer request and an estimated departure time from each PEV and then allocate the available facility power while minimizing any PEV customer disappointments. An EMS is capable of holding aggregate PEV demand to a hard facility limit, but this could result in significant PEV customer disappointment.

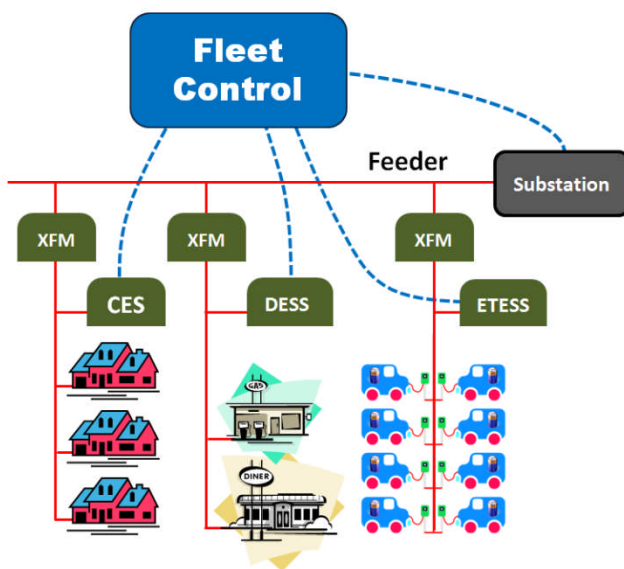
A New Concept for Grid Storage

Community Energy Storage (CES) is a new concept for grid storage that was developed by American Electric Power (AEP). A CES unit has a power of 25 kW with up to three hours of storage at rated power. It connects to the 240 volt secondary of the pad mounted transformer serving a group of homes. These units can act autonomously to control real and reactive power along a distribution feeder and they can also be aggregated as a fleet to form a large virtual storage system to serve the larger needs of the grid – for the feeder, the substation, or the control area. During power failures the units can disconnect from the grid and be islanded to provide power to the residences served by the transformer and improve power quality. With support from Federal Stimulus grants, AEP will be demonstrating a distributed two MW storage system in Ohio using 80 CES units and DTE Energy will be demonstrating a 500 kW system in Michigan that uses 20 CES units.

In 2010 the Electric Power Research Institute (EPRI) expanded on the CES concept to include units at power levels from 25 to 75 kW on single phase circuits and up to 200 kW on three phase circuits. They call it a Distributed Energy Storage System (DESS) – Utility Padmount. The Smaller 25 to 50 kW (CES) units would be deployed in residential applications and the larger 75 to 200 kW (DESS) units would be deployed in commercial and industrial applications.

Combining Grid Storage with a Charging Facility EMS

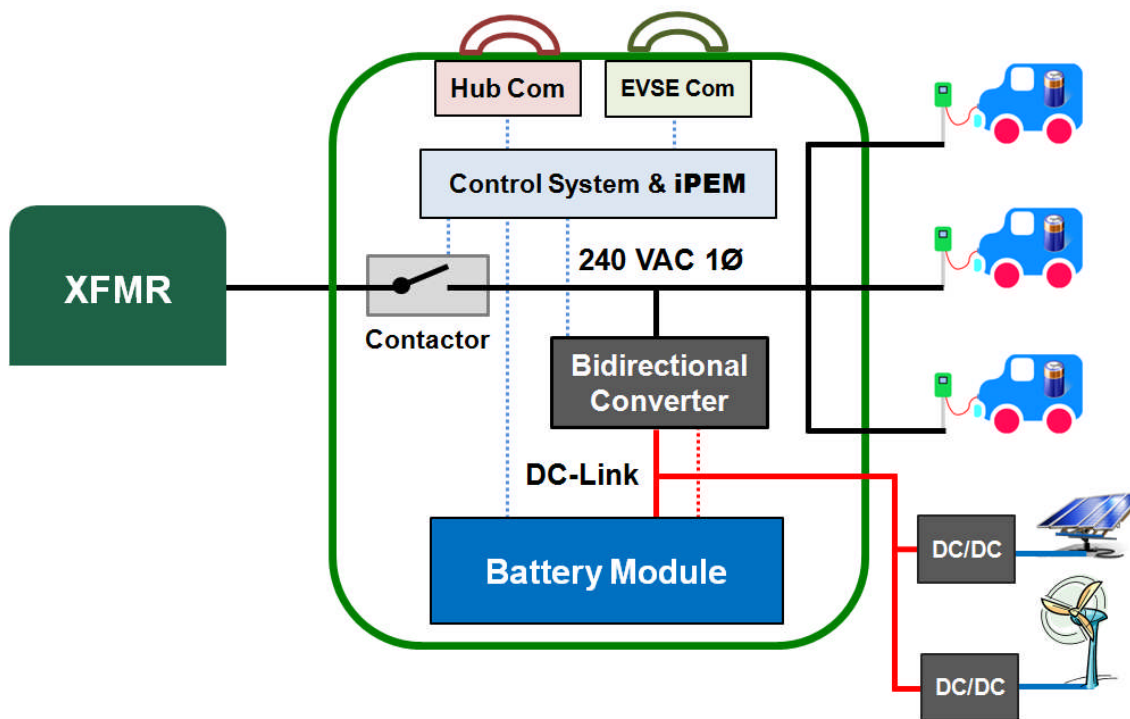
A facility EMS with iPEM logic provides the capability to control the total facility power demand. It can increase or decrease the rate of charging for each of the connected vehicles to control the aggregate facility power. But it cannot add power, and this increases the risk that some vehicles will not get their requested energy transfer. However, if a grid-connected, energy storage system is placed within the facility, the iPEM algorithms can now take advantage of the energy storage capability to further improve the optimization. The iPEM logic can now add power. This integrated system of iPEM logic and energy storage is called an **Electric Transportation Energy Storage System (ETESS)**.



ETESS could be used exclusively for managing PEV charging loads within a facility. However, it is also possible that an ETESS unit could support the needs of the grid outside of the facility as a Distributed Energy Storage System (DESS). ETESS can be thought of as just another DESS application, except it is connected to a group of charge stations at a parking facility rather than to homes or businesses.

The ETESS Architecture

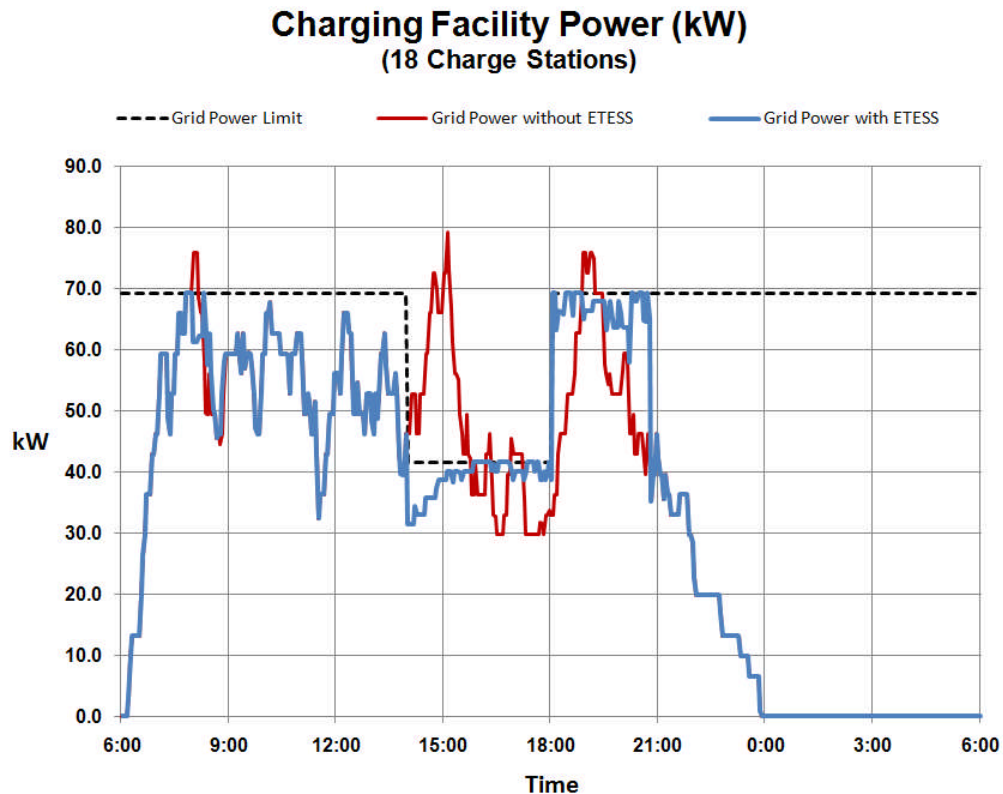
A simplified block diagram of an ETESS unit is shown in the figure below. This block diagram looks almost identical to that of a CES unit except the IPEM logic has been added to the control system. The diagram only shows three vehicles but there would normally be many more. The bidirectional converter connects to the AC power line. It converts AC power to DC power to charge the battery and acts as an inverter to convert battery power to 240 AC power. The diagram also shows that renewable energy sources can connect to the DC-Link using DC to DC converters. This is another potential benefit of having an ETESS unit at a charging facility. The ETESS unit communicates with the utility or another higher level control using the Hub Communications link. This can be any type of communication system and will be site dependent. The ETESS unit also communicates with each charge station at the site. This will also be installation dependent and can use power line carrier communications, optical fiber, cable, or wireless.



ETESS is sized at the high end of the EPRI DESS range for single phase units (75 kW – 225 kWh), primarily because it can be placed at commercial business locations without becoming obtrusive. This was a primary consideration in sizing CES for residential applications. This level of power and energy may be more than is needed for use solely with the vehicles, but any excess capacity would be available for external grid applications.

ETESS at Work

ETESS can use its stored energy to maintain the total power demand of a charging facility below a grid power limit while satisfying the aggregate power demand of the PEVs. This is illustrated in the chart below which was generated using a multivehicle charging simulation. This simulation example uses 18 AC Level 2 charge stations. The dashed line shows two overlapping grid power limits: a flat limit at approximately 70 kW that represents an infrastructure limit and a demand response notch from 2:00 p.m. to 6:00 pm where the facility is expected to stay below 42 kW.



The red line shows the power demanded by the charging facility without ETESS. The vehicles connect and immediately start charging at the rated power of their on-board chargers and continue until the desired energy transfer is completed. The grid limits are exceeded and one of the highest peaks occurs during the demand response window. The blue line shows the facility power demand when ETESS is engaged for the same scenario. The blue line covers the red line when the power demand is equal. All of the limits were protected and no vehicles were disappointed.

This is ETESS at work. Its embedded iPEM logic can effectively manage the aggregated power demanded by the PEVs. Its stored energy helps greatly with minimizing PEV customer disappointment while managing to grid power limits. Its stored energy can also be used to provide voltage support, load following, or other services for the grid.

To learn more about ETESS, visit the AEYCH LLC website at www.aeych.com.