

PLUG-IN ELECTRIC VEHICLES AND RENEWABLE ENERGY INTEGRATION

SCOTT PETERSON AND VANESSA SCHWEIZER, CARNEGIE MELLON UNIVERSITY

Renewable energy sources such as wind and solar are variable and intermittent, requiring some form of backup generation or energy storage to ensure reliability. One proposed solution that could be available in the future is to use battery storage onboard electric vehicles. The Nissan Leaf, an electric vehicle (EV), reported to have a 100-mile range, has 24kWh of onboard energy storage; the Chevrolet Volt has 16kWh. Plug-in hybrid electric vehicles (PHEVs) also have significant amounts of storage, likely ranging from 4-16kWh. Given 250 million vehicles in the US (1), the amount of storage available has the potential to be quite large. Roughly 20% of vehicles 5 years old or newer are not driven on a given day (2), so the grid could potentially tap their onboard battery storage. If the US fleet were made up of PHEVs with 4kWh battery packs, the daily storage would be more than 150 GWh. With larger 24 kWh packs, the amount of storage available would approach 1 TWh/day. For comparison, in 2009 the residential sector used 4 TWh/day, and the entire electricity sector in the US used 10 TWh/day (3). Also for comparison purposes, the average daily regulation demand in PJM in 2009 was 20.5 GWh.

Prior work has suggested that using onboard electricity storage would be profitable for first movers providing ancillary services (4). The number of vehicles necessary to saturate markets for these services is relatively small (<200,000 for California), but the need for such services will likely increase given greater integration of variable and intermittent energy resources (4). It has also been shown that it will be possible to use onboard storage for peak shifting (energy arbitrage), but profits will likely be too small to interest owners due to the high cost of batteries and small margins (5). To facilitate any form of vehicle-to-grid (V2G), it will likely be necessary to convince automobile manufacturers to warranty batteries for a specific amount of energy throughput and to permit V2G energy transfers. Otherwise, there is no reason they would provide warranty service to owners that use the battery for V2G, decreasing its lifetime.

In addition to supporting ancillary services and providing energy arbitrage, other methods to utilize PHEVs for grid support should be investigated. One promising direction is similar to direct load control. Vehicles could respond rapidly to changing conditions on the grid while charging. It would not place a cost on the owner in terms of battery degradation to slow the charge rate dramatically if fluctuations in intermittent resources require it. This is similar to regulation, but no energy would be provided to the grid. In addition vehicles are likely to be available to charge in the night when wind power is usually highest; this synergy would be maximized if the vehicles charge at night only during periods when wind power generation is actually high. This could potentially avoid spilling excess wind capacity thus increasing wind utilization and helping meet renewable portfolio standards (RPS). In addition, by avoiding sending energy back to the grid, excess battery degradation is avoided.

1 http://www.bts.gov/publications/national_transportation_statistics/html/table_01_11.html

2 <http://nhts.ornl.gov/download.shtml>

3 The Energy Information Administration (EIA) reports that in the rolling year from March 2009 – March 2010, the residential sector used 1380 TWh, while all sectors used 3695 TWh. See http://www.eia.doe.gov/cneaf/electricity/epm/table5_1.html

4 S.E. Letendre, W. Kempton, The V2G concept: a new model for power? Public Utilities Fortnightly, February 15, 2002, pp. 16–26.

5 S. Peterson, J. Apt, J. Whitacre, J. Power Sources 195 (2010) 2377–2384.

There are advantages to using PHEVs for V2G services. Batteries respond in times of milliseconds, so the ramp rate is extremely fast. They are also likely to be widely distributed, reducing grid congestion. Currently, natural gas and hydro generators, where available, are used to firm intermittent resources due to their fast ramp rates. The fast ramp rates inherent in PHEVs might allow generators with slower ramp rates to firm intermittent resources. This could potentially decrease the cost of integrating greater amounts of intermittent resources. It also has the potential to reduce the need for spinning reserves. To properly estimate whether energy storage using vehicle batteries could increase the feasible amount of variable and intermittent energy sources, it is essential to know a number of things. First, the number of vehicles, state of charge of vehicles throughout the day, and time those vehicles would be plugged in must be determined. This information allows the demand to be predicted throughout the day. It should also be possible to determine the amount of storage available at any given time. Vehicles spend most of the time parked, but a parked vehicle may not be plugged in. That depends not just on the installation of charge points in accessible, or even preferred locations, but also on user behavior. Charge points installed for PHEVs should require that the vehicle be plugged in to use the spot. If the electricity were free to the user, then it is likely vehicles would be plugged in. However, if the price for charging is higher than what the owner would pay at home (perhaps to pay for the installation of the charge point or due to real time pricing), it is equally plausible that an owner would not agree to plug in.

Vehicle-to-grid applications also face a number of technical and political hurdles. The national electric code will need to be updated to ensure vehicles do not send power to the grid when grid operators turn electricity off purposefully (for maintenance or blackout restoration), and communications between vehicles and grid operators will be necessary. Otherwise a line worker might get electrocuted when a vehicle sent power to the grid. Vehicle owners will need to be convinced that allowing some control to a third party is acceptable. Vehicle manufacturers must be convinced that the use of vehicle batteries for V2G services will not harm them. It is not clear that there will be sufficient incentive to use PHEVs to supply power to the grid in most cases. However, it is possible that the prices of batteries will fall sufficiently to gain sufficient market share that they will be able to enter niches currently served by other methods. For instance, once batteries become cheap enough, novel business models involving battery aggregators might alleviate the concerns of vehicle owners and manufacturers. Aggregators might allow third party control over large numbers of batteries and would manage large stocks and flows of charged, charging, and degraded batteries.

Even with all of these challenges, it is still possible that instead of introducing further risk into operation of the grid, PHEVs and EVs can be used to increase reliability and decrease the cost of operating the grid, while at the same time increasing the amount of intermittent resources that can be integrated. Research at RenewElec can address these questions through a number of initiatives. Estimating likely profiles for the state of charge in vehicle batteries will help to predict the magnitude and timing of load as well as capacity to provide energy to the grid. Battery degradation testing can help quantify the economic value of charging batteries at different rates. Efforts are also underway to analyze the relationship between load timing and magnitude from PHEVs and wind generator output.

1 http://www.bts.gov/publications/national_transportation_statistics/html/table_01_11.html

2 <http://nhts.oim.gov/download.shtml>

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