Exploiting PEV Batteries For V2X Applications (/bulletins/may-2017/exploiting-pev-batteries-for-v2x-applications)

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In a number of emerging and growing applications, the batteries of the plug-in vehicles (PEVs) when connected to the grid, homes, or buildings, can provide temporal "buffer" zones that can decouple the time when generation is available and when demand occurs. This buffering is achieved by storing energy during certain periods (e.g., off-peak hours) and feeding it back to the grid when needed. These applications are, collectively, referred to as vehicle-to-X (V2X) services, where X can represent the grid (G), a building (B), a home (H), or other PEVs (V). Developing and promoting widely such V2X applications has two major advantages: the first is that it can enhance the efficiency of grid operations and, second, it can facilitate the mainstream adoption of PEVs.

PEV Mainstream Adoption

Even though the penetration of PEVs has been ramping up over the past few years, the cost of owning one is relatively higher compared to the traditional gas-powered options. On the other hand, lower maintenance costs and monetary incentives (i.e., 7500 USD in the US) have boosted PEV adoption rates. In Norway, incentives such as free public charging and 25% sales tax exemption translated to PEVs representing a whopping 40% of the new vehicle registrations in 2016. In order to provide additional incentives to facilitate mainstream adoption, the batteries of "plugged-in" PEV (i.e. parked and charging, not on the move) can be used as distributed power sources offering ancillary services, such as frequency response and backup resources during emergencies.

Enhancing Grid Efficiency

The century-old electrical power grid is kept operational based on a simple principle: continuous matching of supply and demand in real time. Ensuring such a balance across large geographical areas, in some cases between countries or continents, requires advanced measurement, monitoring, control, and communication technologies. Traditionally, dispatchable sources such as thermal, hydro, and nuclear power plants are scheduled based on the economics of supply and demand in which the output of power generation is set to follow customer demand trends. In some cases, demand is so high that system operators need to carry out costly generation dispatches. Generation is also deployed or procured to endure stochastic customer demand, system imbalances, operational failures, or, in extreme cases, power market dips. In such extreme cases, if no action is taken, operators might be led to pay customers to consume electricity during the times of excessive renewable energy generation.

The status quo has remained largely unchanged due to the limited ability of storing energy cheap. For instance, the energy storage capacity in the United States is one fiftieth of the electricity generation capacity. Furthermore, the vast majority of aggregate storage ability comes from mechanical storage options, e.g., pumped hydroelectric and compressed air energy storage systems, which rely on the availability of specific geographical resources such as running rivers, falls, and caverns. Energy storage through chemical, electrochemical, or electric-field technologies, however, has been limited. However, the flexibility enabled by chemical storage units is becoming increasingly necessary in order to integrate and rely on renewable energy sources, and implement dynamic, real-time demand response. Such concerns become even more pressing when they are coupled with the gradual retirement of conventional power plants (e.g., coal and nuclear), which have historically provided real-time response.

PEV Battery Technologies

The PEV battery market is currently dominated by Lithium-ion technology. The capacities of battery packs of this chemistry vary in the range of 16-60 kWh (most common designs/applications), which can support all-electric driving ranges up to about three hundred miles (as from published research and industry results considered here). PEVs are usually parked and charging for long periods of time, while a fully charged long-range PEV battery can support the driving needs of two or three days of average daily driving distances (e.g. ~40 miles in the U.S.). Based on the physical characteristics of the batteries, and the driving patterns of the respective PEVs, these batteries can also be deployed in a number of additional capacities as listed next.

Vehicle-to-Grid

Real-time ancillary markets have been established to fine-tune the supply-demand balance. This requires various actions to be taken at different time scales spanning from milliseconds up to five minutes. One of the standard practices, is to inject power to the grid, or draw power from it via contracted agreements. In a vehicle-to-grid (V2G) application, PEV batteries can participate in the ancillary services market, such as frequency regulation and reserves, and their batteries can be charged and discharged to support the grid within the specified operation limits. Due to minimum power and energy requirements, only a group of PEVs can engage in ancillary services events and their actions should be coordinated by an aggregator. Each PEV group can be designed to provide power up to a MW-level. Li-ion batteries are appropriate choices for such applications due to their fast response and quick discharge characteristics. For instance, in 2014 a partnership between PJM Interconnection and the University of Delaware enabled 15 PEVs to serve the grid as regular power sources in the scope of a V2G test application.

Vehicle-to-Building

PEV batteries can also be deployed in large buildings such as hotels, business centers, and malls for peak shaving applications to cut down the energy and the demand charges. Such applications, known as vehicle-to-building (V2B), can provide emergency back-up during black-out periods. Moreover, V2B can support the zero-energy buildings concept by storing renewable resources during off-peak hours and allowing the building to consume it during peak-hours. V2B can be performed via bidirectional chargers located at the parking lots of the buildings. Depending on the size of the buildings, a few PEVs could be adequate to meet the power demand.

Vehicle-to-House

Similar to V2B, a PEV can be connected to a single house to participate in a vehicle-to-home (V2H) application, to provide power during peak hours, store renewable energy, and act as an emergency back-up during blackouts. The difference between V2H from V2B is that, typically, V2H serves significantly smaller loads, in terms both of peak power and of daily energy. In fact, there are already commercially available PEVs that can support an average, energy efficient household.

Vehicle-to-Vehicle

The last application is vehicle-to-vehicle (V2V) in which groups of conveniently located (in parking lots in malls, schools, and workplaces) PEVs exchange energy with each other. In V2V services, a group of the PEVs who have extra stored energy act as the sellers, and the rest as the buyers. V2V applications can take place in two occasions: (i) when the sellers accept to participate in auction sessions with a price that is lower than the utility price, and (ii) during blackouts when the grid power is not available.

Conclusion

The acceptance and success of V2X applications require performing the necessary cost-benefit analyses by taking into account various factors that represent the cost incurred due to battery degradation on the one hand, and the benefits of enabling new technologies, on the other hand. Furthermore, the ratio of peak to off-peak tariffs should be also properly assessed. Specifically, as this ratio grows, higher profits can be achieved by storing off-peak energy. Based on such analyses, the pricing regimes can potentially become remarkably different. Some utilities have already started to apply demand charges for residential customers, a practice which can boost the need for V2H and V2B applications. To this end, case-by-case business models need to be developed in order to assess the profitability of V2X systems.

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