AC PROPULSION

Electric-drive vehicles have within them the energy source and power electronics capable of producing the 60 Hz AC electricity that powers our homes and offices. When we allow this electricity to flow from cars to power lines, we call it "vehicle to grid" power, or V2G. Cars pack a lot of power: one typical electric-drive vehicle can put out over 10kW, the average draw of 10 houses. There are 250 million registered cars in the US. Imagine if we could harness even 2% of that energy: 50 million homes could be powered!

Background

US passenger vehicles are, on average, parked and idle for about 23 hours each day. During this time, they create no value for the user, and there exists an associated cost because they need to be stored – parked – while not in use. With the advent of electric vehicles, there is the prospect that idle vehicles can create value to their owners while parked. By connecting such vehicles to the electric power grid, a large scale, dispatchable electric power generating resource is created.

As cars and light trucks begin a transition to electric propulsion, there is potential for a synergistic connection between such vehicles and the electric power grid. In fact, the aggregate power rating of the US vehicle fleet is much larger than the total US generating capacity. If even a small fraction of vehicles could be harnessed as generating assets, both the electric power grid and to the vehicle owners could see enormous benefits. The potential exists for the economic value generated to offset the costs of electric vehicles.

Types of Energy Services Vehicles Could Offer

Grid connected vehicles can support the grid in a number of ways. Depending on the vehicle and the needs of the driver, the grid support services would be available whenever the vehicle is plugged in -- typically at the vehicle driver's home or place of work.

> **Peak power sales**
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> Grid-connected vehicles could be aggregated by an energy services company to provide power into existing markets. The most likely is the same-day/hour ahead market.
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> **Spinning reserves**
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> The Independent System Operator (ISO) is required to maintain sufficient reserve generating capacity available for immediate power production. The term 'spinning' derives from the definition that spinning reserves must have generators spinning and synchronized with the grid, ready for immediate power generation.

EVs can provide equally-fast power on demand, with the added benefit of little or no 'spinning' or idling losses.

Base load power

Base load power involves contracting to provide power for extended periods. This energy could be sold directly to a business that owns the parking space (such as an employee's place of work). Hybrid or fuel cell vehicles for which the grid interconnection also includes a source of fuel are the most viable here.

Peak power as a form of direct load control (DLC)

Utility companies have forms of direct load control (DLC) in which they pay their customers for the right to interrupt power to certain loads when system demand is high. For example, in California, these are typically targeted at residential air conditioning systems. In a similar fashion, a utility could contract with a vehicle owner or system aggregator to be able to directly control power delivered by connected vehicles – the system-effect of which is the same as directly shutting off loads.

Peak power to reduce demand charges

One of the simplest forms of service is to locally control the vehicle power output in a way to reduce the peak power demand of a business. By having fast-response power capacity on the customer side of the meter, the peaks of a businesses power demand can be provided by connected vehicles. This will reduce the demand charge the business pays to the electric utility. If the demand charge is based on kVA rather than kW, then the connected vehicles can also function to supply the businesses reactive power needs, and hence reduce the kVA seen by the utility. Demand charges typically range from $5 to $15 per kW (peak 15 min average power) per month.

Reactive power

Utility companies must provide reactive power (VARs) to meet the non-unity-power-factor loads of its customers and to maintain overall system stability. Large numbers of vehicles with inverter connections to the power grid offer the potential for localized production of VARs to meet the needs of the distribution utility.

Other value created

There are numerous other values created by distributed generation or storage but are not as directly quantifiable as those above. These include:

Deferral of transmission distribution and capacity investment

By getting more energy delivered into regions where the distribution grid has reached its capacity, it will be possible to defer costly upgrades to the system.

Potential emissions reduction

Energy stored in electric vehicles or produced by fuel cell vehicles has the potential for reducing local emissions. For hybrid vehicles, local emissions will have to be evaluated to determine whether there are any benefits compared to central power plants.

Potential for cogeneration

In the case of fuel cell or hybrid vehicles, power generation will also produce waste heat. It may be possible to capture this heat for beneficial purposes, but this will entail adding a heat transfer loop into the interface between the vehicle and the grid.

Reduction of transmission losses

Since power can be delivered at or near the point of end-use, losses associated with delivering the power are nearly zero.

Battery Electric Vehicles

Battery powered electric vehicles are different than hybrid or fuel cell vehicles for this application in that they don't generate electricity. They are instead a distributed storage medium that time-shifts the generation and consumption of electrical energy, providing, for example, peak power, reliability, distributed storage, and reactive power. There are associated losses and battery costs that must be factored in to any economic analysis. When considered only for daily peak or base-load power, the economics may not be favorable to battery storage because the resulting battery wear-out costs per kWh are too high.

There are two areas in which the economic viability needs to be explored. First, other energy services, including hour-ahead, spinning reserves, and others can have high values, above their cost in battery wear-out. Second, batteries for electric vehicles have two general types of wear out. These are: degradation due to use (cycling) and degradation due to calendar time. There is some evidence that suggests that calendar life may prove to be the life limiting factor for some EV batteries. If this is the case, the incremental cost of additional cycling within the calendar life may be small or even zero.

Some of the value-generating services that could be offered by electric and hybrid vehicles don't require significant energy transfer. For example, peak power sold as spinning reserves to the ISO or dispatchable power to the distribution company may be activated only a few times per year. Reactive power or grid support services would not require any net energy flow from the vehicle. A sample daily energy profile of an EV that is operated in a daily cycle to deliver power to the grid at peak hours is shown below. Below the energy profile is a sample graph of power demand in California.

Hybrid Vehicles

Hybrid electric vehicles powered by internal combustion engines could also have the capability to produce power for the grid. Current hybrids like the Toyota Prius and Honda Insight run on gasoline. Running at 18 kW electrical power to the grid, such a vehicle would burn through 10 gallons of gasoline in about 5 hours. This would require vehicle drivers to refuel their cars very often – an inconvenience at best, and unacceptable at worst. A more practical alternative could be to provide the fuel from the infrastructure side – low-pressure natural gas might be practical, and could produce very low emissions.