GREEN OVATIONS

Innovations in Green Technologies

Electric Vehicles Could Offer More Gain than Drain

By Dr. Mladen Kezunovic

Plug-in hybrid vehicles and battery electric vehicles pose a number of challenges for aging power infrastructures, including the potential to accelerate the aging of power transformers. But they also have the potential to play a role in smart grids as distributed energy sources to support demand side management and outage management programs.

Electric vehicles are gaining popularity with consumers as manufacturers invest in research and development to create more affordable plug-in hybrid vehicles (PHEVs) and battery electric vehicles (BEVs) that have greater energy storage capability and low-cost smart charging.

There are multiple studies using either statistical or predictive models to forecast the penetration of EVs; one estimates that by 2030 their market share could reach as much as 25 percent, while another predicts 20 percent by 2040. Most projections show that a significant amount of EV penetration is expected to occur within the next 30 years.

But as automakers respond to the demand for EVs and begin to realize a viable business opportunity, it creates challenges for utilities, property owners and all levels of governments. For utilities and power grids in particular, EVs mean more pressure on a system that's already heavily burdened.

At first glance, EVs may appear to be just another drain on the grid, but with the advent of smart grids, the adoption of advanced information technology and demand side management (DSM) programs, electric vehicles don't have to be another drain on power grids but instead could play a broader role more efficient DSM and outage management.

New Demands on Old Systems

EVs create challenges for any power grid; in the same way that deregulation and distributed energy resources (DERs) connected to the power grid create more stress by adding complexity and foster security and reliability concerns, EVs are yet another variable with which utilities must contend. To a large degree, smart grid deployment and adoption of advanced information technology are addressing these concerns, while utilities are looking to DSM programs to help them meet the flexibility requirements of smart grids.

EVs are one of the key drivers facilitating deployment of smart grids. If EVs continue to grow in popularity and are able to grab even a small piece of the automobile market, there will be a substantial impact to the power grid. In the unlikely event that all of the 250 million passenger vehicles in the U.S. were electric, each drawing approximately 4 kW and charged simultaneously, the load would be equivalent to the combined U.S. generation capacity of roughly 1,000 GW.

Transformers Must Change

EV charging will have an impact on power distribution, particularly on transformers, which will bear extra loads, as my Texas A&M University graduate student Qin Yan and I discovered through our research based on East Texas load consumption data. Power transformers are one of the most expensive pieces in any power distribution network. As EVs proliferate, a new load peak may be created that exceeds the transformer capacity. For example, a residential house with an EV may mean a need for replacement of a local transformer earlier than originally projected. That reduction in transformer life expectancy will in turn increase costs to utilities and consumers.

Our research used actual 15-minute load profiles from the College Station area of East Texas and explored various charging scenarios that included different charging start times, penetration rates and usage ratios. We concluded that higher penetration rate of EVs significantly increase transformers' loss-of-life factor. However, charging during the night will help to dramatically decrease the loss-of-life factor for all of the scenarios we looked at. In fact, distributed charging could almost eliminate the impact, although the changing seasons would also influence the impact on transformers, and utilities would have to coordinate with customers and charging stations to establish an optimal charging schedule based on actual load profiles.

Charging Must Get Smarter

How the charging of EVs is controlled will play a large role in dictating the impact these vehicles will have on the grid. One worst case scenario is that every driver plugs in their car when they get home from work in the early evening, drawing maximum current charge when the electric load is likely to already be at its maximum and distribution transformers are the most stressed. The effect would not be dissimilar to everyone turning up their air conditioning at the same time during a heat wave.

The key to managing the impact of the EVs on the grid will be intelligent charging, using a time management approach where the smart grid uses information about customer preferences and expected grid conditions to determine the best charging schedule. For example, a car might be charged in the middle of the night when electricity prices and demand on the grid are lowest. Various combinations of best charging times are still a topic of research.

Beyond addressing how these vehicles could be charged in a manner that would mitigate their impact on the grid, there is also a role for EVs to play in DSM and even give back by providing power in a vehicle-to-grid (V2G) scenario, where the vehicle batteries become an integral part of the grid.

EVs Can Give Back

For an electric utility, DSM is defined as 'the planning, implementation and monitoring of distribution network utility activities designed to influence customer use of electricity in ways that will produce desired changes in the load shape.' More simply, the objective of DSM is to improve the reliability of the power supply and create revenue. This might include peak clipping, valley filling, load shifting, strategic conservation, strategic load growth, and flexible load shape.

DSM generally includes two components: energy efficiency, which is designed to reduce electricity consumption during all hours of the year, and demand response, which is aimed at changing onsite demand for energy in intervals and associated timing of electric grid demand by transmitting changes in prices, load control signals or other incentives to end users to reflect existing production and delivery costs. The utility and customer cooperatively participating in DSM will provide the benefits to the customer, utility, and society as a whole.

EVs Could Dispense Energy

Electrical vehicles can be more than just a draw on the grid: they also have the potential to be a DER within a smart distribution system. When an EV is either in V2G mode or vehicle-to-building mode (V2B), it can actually supply power to the grid. Energy stored in an EV could support the local load in the power grid during high system loading and outages, helping to meet power demands and improving reliability.

When connected to the grid using a plug, EVs use electricity from an electric power grid to charge their battery – this is G2V mode. But it can also discharge electricity to a building while it is parked or during an outage – V2G or V2B.

PHEVs could be used to address load levelling, regulation and reserve, research has found, and there are a number of benefits from using EVs to participate in DSM as DERs in a smart distribution grid.

Research has been done to look at the potential benefits of EVs as dynamically configurable dispersed energy storage, both in terms of supporting DSM and outage management initiatives. Most of the time, vehicles are parked at homes, in parking lots, on streets and in garages – the perfect time to leverage their battery capacity. In V2G mode, EVs could act as decentralized energy storage in a smart grid, acting either as a load or generator as required.

V2B mode works differently but ultimately serves the same goal of energy efficiency. In this situation, power is exported from the vehicle battery into a building – vehicle batteries serve as a generation resource for the buildings through a bidirectional power transfer through energy exchange stations at pre-determined times. The benefit would be a more reliable distribution system while providing economic benefits to vehicle owners and potentially reduce the purchase cost of the building's electricity.

DERs are parallel and stand-alone electric generation units located within the electric distribution system at or near the end user. DERs can be beneficial to both electricity consumers and utilities if the integration is properly engineered. While the centralized electric power plants will remain the major source of electric power supply for the future, a DER complement central power generation by providing incremental capacity to the utility grid or to an end user.

Installing a DER at or near the end user can also in some cases benefit the electric utility by avoiding or reducing the cost of transmission and distribution system upgrades. As one important technology used in configuring DER, energy storage technologies can deliver stored electricity to the electric grid or an end-user, which could be used to improve power quality by correcting voltage sags, flicker, and surges, or correct for frequency imbalances.

As with most vehicles, EVs spend most of the time sitting idle, so their battery capacity can be fully utilized during such times and serve as DER. When aggregated in sizeable numbers and capable to operate in the V2B mode, they could act as generator and even play an important role in outage management; their batteries could be used as emergency back-up power for commercial facilities or other large buildings.

V2B before V2G

V2B is a concept that is practically viable today because it is far simpler than V2G. Conceivable, V2B could be implemented within the next three to five years, while the horizon for V2G is farther out: It will likely take 10 to15 years to gain wide acceptance. One of the primary reasons V2B is likely to gain traction sooner is the availability of EVs in major cities due to early adopters. In the next few years there could be a critical mass of vehicles for aggregated use. And with the development of smart garages that can provide an interface between the transportation network and electric power system, the vehicle charging/discharging infrastructure and control system is available to make V2B not only viable, but economically attractive.

There are a number of key considerations that must be taken into account when implementing V2B, starting with batteries, which are one of the most important components of EVs. Research has shown that advanced battery technology is adequate to support most of the available vehicle models, while battery capacity depends on the electric range and the vehicle electric drive efficiency. However, there is still a great deal of uncertainty surrounding what is the most economical size and configuration of marketable EVs when comparing the battery pack size and technology, electric motor size and IC engine size.

Another critical factor in V2B implementations is data availability from a variety sources, including power system static data; real time topology information and load data; event data; location data, including that of the fault, the building which is out of electricity, and possible location of PHEV/EBV battery generation; availability and possible amount of generation; the status and performances of charging stations; and, the price of charge/discharge.

Both the V2G and V2B scenarios have issues, however. The value of having these idle EVs as an available power source to the grid must be balanced with the inefficiency of reverse power flow and the impact on battery life, which in turn raises issues of who will bear the cost of the battery warranty and replacement.

Mind Your Station

One of the key physical components that must be addressed is the energy exchange station for G2V and V2G. There are at least two forms these stations could take; the first one assumes that individual drivers plug in and charge their vehicle over a period of several hours, much like they plug in their smartphones. These stations would not be limited to their home; charging stations could be located at shopping malls, recreational areas, schools, and other locations frequently visited by drivers where their vehicles may sit unused for a minimum period of time.

However, instead of requiring drivers to plug into the grid and wait several hours to charge their batteries, battery exchange locations could be as ubiquitous as gas stations and automatically exchange discharged batteries with fully charged batteries, which would certainly be more appealing to drivers. This system of leasing batteries would alleviate consumer concerns about battery life and warranty while utilities would benefit from centralized control over charging and servicing the grid.

In likelihood, we will see a combination of these two approaches. Depending on the pricing and incentive structures in place, it may make sense for drivers to exchange batteries during long drives and plug in to a household plug at night.

The Road Ahead

In order for faster and significant adoption of EVs to occur and for them to be efficiently integrated into the power distribution system, a great deal of modeling of complex systems must take place as well, starting with the interactive performance of power and transportation systems. And while economic feasibility will play a large role in determining the growth rate of EV usage and effective integration into the power grids to realize the benefits of G2V, V2G and V2B, it's people who are in the driver seat: Widespread adoption EVs will place human vehicle operators at the intersection of power and transportation systems, so understanding human decision making within the context of EV usage will be a critical factor moving forward. Further research is needed to further develop the proposed concepts. Research organizations such as the National Science Foundation's Center 'EVs: Transportation and Electricity Convergence' are making contributions to bring the proposed concept to practical fruition.

About the Author

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