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Electric Vehicles in a Distributed Energy World – Spotlight on a Transformative Technology

After being condemned to a premature death sentence in the mid-90s, the electric vehicle (EV) is back. And not only is it back, but this time the EV is poised to become the future of transportation.

The Brief

Economic, environmental, technological and regulatory incentives have converged to push EVs over the technology tipping point, much like what the world experienced with the evolution and growth of intermittent renewable energy.

Like wind and solar, EVs will also have a fundamental impact on the energy industry and the supply/demand balance of our power grids. However, where wind and solar bring the challenges of less predictability at the edge (and in some cases reduced utility revenues), EVs, on the other hand, bring opportunities. With the potential to integrate vehicle batteries in a way that can mitigate the grid balancing challenges of renewable intermittency while also creating enhanced revenue streams, EVs enable the grid to be more reliable and flexible.

As a result, conversations in utility board rooms around EVs are shifting dramatically from a previous focus on EVs as potential grid destabilizing problems – to EVs as a unique opportunity to achieve heightened levels of positive customer engagement while balancing supply and demand swings and enabling new ways to participate in wholesale energy markets.

The opportunity is large for those utilities who are positioned to embrace EVs as distributed energy resources (DERs) that are aggregated, optimized and controlled by virtual power plants (VPPs) and distributed energy resource management systems (DERMS). This, in turn, allows for EVs to be vital and healthy components of the power grid.

The Burgeoning EV Market

There is widespread agreement among market analysts and researchers that mass market adoption of EVs is imminent. As of 2018, the electric vehicle global stock amounted to 5.12 million vehicles, mainly purchased in China and the United States. About two-thirds of these vehicles are battery electric vehicles (BEV), with the remainder being plug-in hybrid electric vehicles (PHEV).

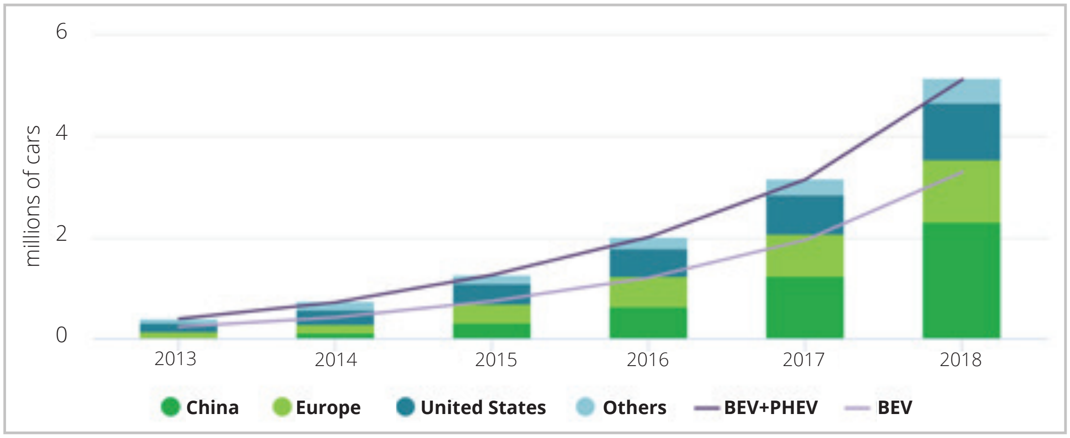

Figure 1: Passenger electric car stock in major regions (Source: IEA)

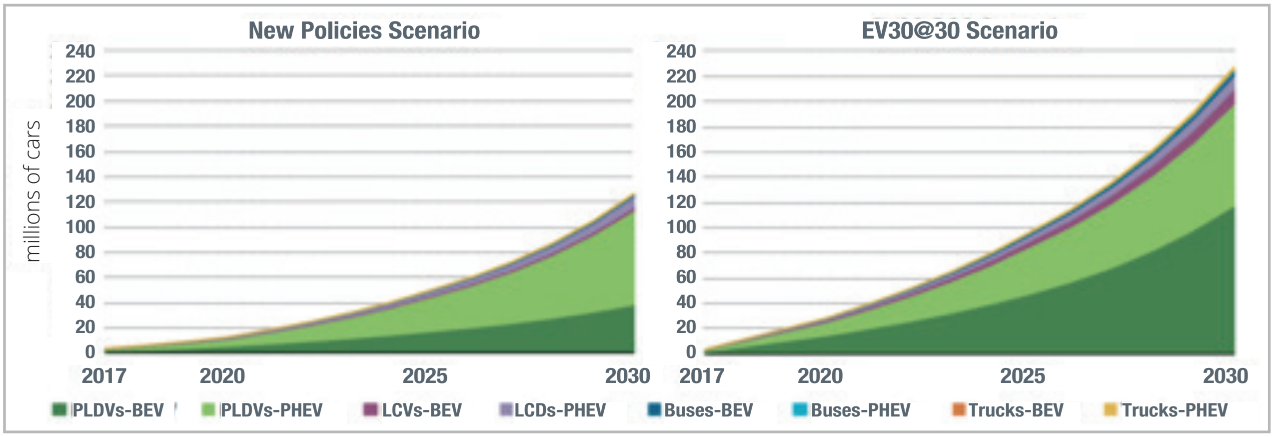

Figure 2: Global EV stock in the New Policies and EV30@30 scenarios, 2017-30 (Source: IEA)

Although these 5.12 million EVs represent less than 1% of the global car fleet today, the International Energy Agency (IEA) forecasts over 120 million EVs by 2030.[1] This number increases to over 220 million in an ambitious policy scenario proposed by the Clean Energy Ministerial (CEM), aiming for 30% of all new vehicle sales to be EVs by 2030 (EV30@30).[2] Similarly, Bloomberg New Energy Finance expects the 1% penetration today to grow further to over 30% of all global passenger vehicle fleets and medium commercial vehicles by 2040.[3]

The major drivers for this growth include the declining cost of batteries, the overall economics of EV ownership and government initiatives resulting from aggressive CO_2e emission reduction targets.[4] By 2020, the EV cost of ownership is expected to reach a breakeven period of 3-5 years, on par with the cost of a traditional car or truck. With the declining cost of ownership, an increase in EV options from virtually every automaker and a trend towards environmental policies that encourage the reduction in greenhouse gas emissions, EVs are expected to outsell conventional vehicles by 2030, according to Felipe Munoz, a global analyst at JATO.[5] Other analysts believe the migration from conventional to EV might be slower, but most agree it's coming. This growth is expected to bring with it the most significant new electric load since the rise of air conditioning in the 1950s,[6] and as we've seen repeatedly (with smart phones and solar PV), predictions for uptake rates of new technologies are generally underestimated.

Help or Hindrance? It Depends.

While an increase in basic load growth is good for utilities, the uneven distribution of large loads within a focused location or at a specific time of day is not. If charging cycles are not intelligently optimized around existing electric usage, it will force the inevitable growth of EV loads, which could lead to significant operational challenges for grid operators. This, in turn, could force utilities to invest billions of dollars in distribution upgrades to maintain reliability and prevent distribution circuit overload and under-voltage issues, along with additional peaks that can occur when EVs are being charged.

Fortunately, purposeful optimization of the growing EV fleet can make EVs an asset rather than a risk to the grid. Thanks to evolving technologies and business models that manage and spread the load across both infrastructure assets and time via smart charging, vehicle-to-grid integration (V2G) and today's distributed energy resource aggregation, orchestration and real-time control/dispatch platforms. Such approaches can minimize, defer or even eliminate the need for infrastructure upgrades – and can also decrease grid balancing costs by feeding battery energy back to the grid to facilitate ancillary services and provide numerous additional benefits.

- EV chargers can receive and respond to signals through which customers can easily enroll in demand response programs, which are, perhaps, the "low hanging fruit" of the shifting EV paradigm.
- EV batteries can respond very quickly and accurately to grid signals, enabling them to act as on-demand assets for load shifting and grid operations. This can provide load relief in times of peak demand and excess solar generation.
- On-board charging intelligence within EVs, combined with EV supply equipment (ESVE), enable the automatic shifting of EV charging times when demand is low, without negative impact to the EV owner.
- Controlling EV charging actively with other DERs within a VPP or DERMS will provide the stacked value to support DER market participation for effective grid stability, while deferring the need for traditional distribution grid upgrades.
- By leveraging rapidly evolving V2G technology, there is a whole new opportunity for EVs to participate with other DERs in wholesale markets, thus becoming a multi-use asset with maximized economic value.

Real-Time Smart Charging

Today, EV charging typically occurs at times where peak demand is already high, for example, when people arrive home from work in the early evening. To mitigate this, some utilities have introduced clock hour-based charging programs. These are passive, managed-charging programs[7] that include:

- EV time-varying rates, including time-of-use (ToU) rates and hourly dynamic rates
- Behavioral demand response – communicating to customers to voluntarily reduce charging load during peak hours
- Incentive programs rewarding off peak charging

Utilities that have launched passive charging programs have found that they successfully reduce demand during the program window, but once the window closes, they then see a ramp-up in charging, which has the potential to create a new peak at a later hour.

Positive Externalities at the Parking Lot

Major factors contributing to the Transportation as a Services (TaaS) business model include car-sharing services becoming more commonplace in major cities and advances in autonomous ride-hailing services. TaaS will mean higher utilization of fleet-owned passenger vehicles, while the purchase and use of the privately-owned passenger vehicle will decrease. Not only does this provide grid benefits through managed EV charging and V2G technology, it's also expected to decrease traffic congestion and reduce the square footage required for parking lots. This means less pollution and waste – freeing up land for densification, community engagement and economic development projects.

> **"Utilities are uniquely positioned to take critical proactive steps now before EV adoption rates accelerate, laying the groundwork to optimize policies, regulations, standards and protocols for the future so that EVs can be valuable grid assets."**
>
> *–Erika Myers*
> *Principal of Transportation Electrification, SEPA*

From the owner's perspective, the actual time of charging doesn't really matter – as long as the state of charge is at an acceptable level when the vehicle needs to be driven. In other words, there is a window of time between when an EV owner plugs in an EV and when that EV needs to be driven again. This window gives utilities and energy service providers the opportunity to monitor and control charging in such a way that most benefits the grid without inconveniencing the driver.

Technology solutions now exist that provide active telemetry feedback through the EV and EV supply equipment. This telemetry is accessed in real time, providing insights into driving behavior and custom constraints for control at the time of charging. These solutions can aggregate telemetry from multiple EVs and EVSEs within their networks, giving the utility insights into charging activities, and in turn receiving information from the utility on grid conditions.

When there's a need from the grid, for example when demand is peaking, then intelligent control systems can actively manage and reduce the load associated with charging EVs. In the same vein, when utilities with high solar penetration are experiencing excess generation on a sunny afternoon, the control system can actively increase charging of EVs connected to EVSEs, likely at charging stations at the EV owner's place of work, a retail complex or other commercial and industrial locations.

Vehicle to Grid

The V2G component of the EV-to-the-rescue story changes the ROI dynamic by enabling two-way power flows through which EVs can play the same role as static batteries in energy markets, optimizing charging and discharging schedules around the constraints of the EV owner and the price of energy in the market.

Using V2G technology, EVs can send power back to the electric grid when needed to reduce system or local peak demand. Thus, once an EVSE is capable of delivering power from the batteries onboard EVs, V2G enables EVs to be turned into bi-directional virtual power plants through which energy stored in networked vehicle batteries can act as one collective battery fleet to reduce demand, export power to the grid when demand is high and fill demand valleys by automating the charge of batteries when demand is low.

While EVs are starting to arrive at dealerships with this hardware and software installed, it's important to note that commercialization of V2G is still in its infancy.[8] The technology and market are headed in this direction but face barriers such as battery degradation and high investment cost. EV batteries (like stationary batteries) have a certain lifetime of charge and discharge cycles. The more cycles that a battery completes, the faster it will degrade, and, when used in a V2G configuration, also potentially void standard EV manufacturers' warranties. For corporate fleets with pre-determined depreciation on their balance sheets and worthwhile incentives from their electricity providers, this is a reasonable model (once battery costs decrease as expected). However, this is not yet envisioned to be the case for personal ownership.

V2G technology is in the pilot or experimental phase today and not expected to be adopted en-masse soon. However, as we see both utility and vehicle ownership models change – with more peer-sharing services becoming available, a shift towards autonomous vehicles (AVs) and the introduction of autonomous ride-hailing services – there will be a change. Personal vehicle ownership will be replaced with fleet-owned and operated EVs that can provide transportation as a service (TaaS). Within this model, economic trade-offs associated with battery lifespan and utility bills will enable the opportunity for V2G technology to be commercialized and optimized via VPP and DERMS platforms to provide distributed energy as power grids and energy systems transform.

DER Platforms

One critical component of leveraging EVs as grid-balancing, market-feeding resources is the underlying VPP and DERMS software platform they're connected to. This platform is the piece that enables real-time optimization and control of battery fleets, in concert with other distributed energy resources, enabling a mixed portfolio of aggregated DERs to participate in energy markets. VPPs and DERMS platforms are the network orchestrators that control how and when each distributed energy asset contributes to a continuously balanced grid.

There are many EVSE manufacturers on the market – initially these technologies were created to provide the hardware interface between the EV and the power source, but now they are also in the business of providing "hooks" for software to control charging with the capability of demand management.

Value Stacking EVs with other DERs

With the increasing number of DERs worldwide, we see a change in the regulatory environment allowing these resources to participate in wholesale markets. This is a global trend. PJM and CAISO have already developed frameworks for DER market participation in the United States. Sweden is pushing for 50% renewable generation, driving flexibility with compatible market designs. A demand response market is emerging in Japan, while Australia is developing market solutions to deal with both a short- and a long-term capacity crisis from intermittency. Adding EVs to the mix through a VPP and/or DERMS allows utilities to tap into further value creation opportunities. But it's vital to understand that not all VPP and DERMS software solutions are built the same way; utilities must look for a provider with technology agnostic logic and access to a diverse range of communication protocols in order to provide a mixed-DER asset approach and a future-proof solution.

Most of these solutions include an API that can integrate with a VPP or DERMS, allowing EVs to participate in grid services and wholesale markets along with other DERs. The VPP and DERMS platforms act as aggregators, enabling heterogeneous DERs to respond with the same level of speed and accuracy as a conventional and dispatchable centralized power plant.

Effective platforms for EV integration should encompass interoperable, multi-service optimization and reliable real-time, non-disruptive, constraint-based control across a portfolio of DERs. It should also encompass numerous utility use cases including fast demand response, renewable firming, peak demand management, voltage optimization, over-supply (reverse power flow) mitigation, frequency regulation and other ancillary services. Additionally, an effective software platform should enable the EV to participate in wholesale markets through the integration with a virtual power plant.

Given the continuing and rapid evolution of the EV market, the platform must also be highly flexible, with the ability to adapt to new business models as they emerge, as markets mature and as technologies develop. Similarly, the platform's ability to expand to accommodate the exponential growth of EVs and other DERs on the grid is an important criterion for success.

If utilities are going to successfully manage widespread EV growth alongside aggressive climate policies that drive more intermittent renewable generation and DER deployments, they will need to break down their DER silos, become technology agnostic and be able to control and orchestrate hundreds of thousands of disparate DERs, including EVs, within seconds.

Conclusion:

There will be significant impact to the power grid as the transportation industry is electrified. Traditional solutions include major investments in distribution infrastructure to accommodate the increased load. However, more practical and cost-effective methods include real-time control and optimization of electric vehicle supply equipment and the on-board charging intelligence within the EV. These technologies allow the EVSE and EV to respond to grid activities and automatically shift charging to times when demand is low, without negative impact to the EV owner. As wireless charging technology becomes available this will be even more convenient and widely-applied. Controlling EV charging actively with other distributed energy resources within a VPP or DERMS will provide the stacked value to support DER market participation for effective grid stability, while deferring the need for traditional distribution grid upgrades.

In the long term, full vehicle fleets are expected to be electrified within 20 years, resulting in an extensive strain throughout the whole electricity system, including generation. Advancements in vehicle-to-grid technology and shifting business models that include autonomous vehicles and transportation-as-a-service are anticipated to replace the traditional personal owned vehicle model. This transition provides tremendous opportunity for utilities and grid operators to develop programs that orchestrate the use of EVs along with other DERs to meet the growing electricity demand with non-wire alternatives that improve productivity through less congestion while simultaneously reducing greenhouse gas emissions.

Utility EV Innovation: Alectra Drive for the Workplace

Workplace charging is recognized as the second most common charging location for EVs, after charging at home. Alectra Drive for the Workplace ("alectradrive@work") demonstrates the value of integrating smart electric vehicle charging systems at workplaces into the distribution grid to help ensure safe, reliable and cost-effective management of mass EV uptake. The pilot helps to manage the flow of electricity needed to serve workplace buildings and EV charging stations so that electricity costs are minimized for commercial customers while EV drivers have an easy and accessible charging solution.

[1] *International Energy Agency, 2019. "Electric Vehicles, Tracking Clean Energy Progress." https://www.iea.org/tcep/transport/electricvehicles/*

[2] *Clean Energy Ministerial, Electric Vehicle Initiative, 2019. EV30@30 Campaign, Updated: 27 May 2019 – Vancouver Canada (Initial launch: 8 June 2017 – Beijing, China) https://www.iea.org/media/topics/transport/3030CampaignDocumentFinal.pdf*

[3] *Bloomberg New Energy Finance, "Electric Vehicle Outlook 2019." https://bnef.turtl.co/story/evo2019*

[4] *Burch, I., Gilchrist, J. 2018. Survey of Global Activity to Phase Out Internal Combustion Engine Vehicles; Center of Climate Protection: Santa Rosa, CA, USA. https://theclimatecenter.org/wp-content/uploads/2018/10/Survey-on-Global-Activities-to-Phase-Out-ICE-Vehicles-FINAL-Oct-3-2018.pdf*

[5] *NPR.org, 2019. "As More Electric Cars Arrive, What's The Future For Gas-Powered Engines?" https://www.npr.org/2019/02/16/694303169/as-more-electric-cars-arrive-whats-the-future-for-gas-powered-engines*

[6] *SEPA. 2019. "A Comprehensive Guide to Electric Vehicle Managed Charging." https://sepapower.org/resource/a-comprehensive-guide-to-electric-vehicle-managed-charging/*

[7] *Ibid.*

[8] *Delta Energy & Environment, 2018. "V2G: The Journey to Commercialization." https://www.delta-ee.com/downloads/1823-v2g-the-journey-to-commercialisation.html*

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