Grid analyst discusses integrating electric vehicles into electricity distribution systems

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Electric vehicle (EV) adoption is increasing—and fast. At this point, you may own one or probably know someone who does.

As the cost of EVs continues to decrease, the industry matures, incentives grow, and charging infrastructure improves, EVs could make up the vast majority of vehicles on the road in 2050. The U.S. federal government also set a goal for EVs to comprise half of all new vehicle sales by 2030.

Many studies have looked at how increased electricity demand will affect the bulk power system in the United States (spoiler—there will not be big impacts for a while), but public analysis of the impacts on the distribution system has been less prevalent.

Distribution system planners need more information about what to expect so they can strategically plan system upgrades, implement EV charging control methods, and develop new market solutions, if needed, to accommodate EV loads.

That is why at NREL we are researching how to best integrate lots of EVs in electric distribution systems. We are finding that if distribution system planning is done right, there does not have to be much additional strain on the grid, and system planners can largely avoid costly system upgrades—translating to lower retail rates.

Expanding upon existing research

Much of the previous research on EVs and the distribution system has focused on plug-in hybrid EVs, which have smaller batteries; however, more and more people are moving toward fully electric vehicles. Most studies also have not considered EVs with other distributed energy resources (DERs) or EV adoption levels above 40%.

Finally, much of the research has only considered newer distribution feeders where early adopters live and where at-home charging is readily available. But if half of vehicle sales are going to be EVs in 2030, they

will need to charge in more communities with a wide range of distribution grids, including older and already stressed feeders.

So, it is clear that we need more full-scale, realistic distribution system modeling to capture the full range of distribution system voltages and infrastructure ages. Through our work at NREL, we are expanding on the research efforts thus far to look at high adoption rates of long-range EVs, larger distribution test systems with higher levels of DERs, and more advanced EV charge control methods.

Potential impacts to the distribution system with high EV adoption

Electric utilities have traditionally sized distribution feeders based on historical load levels and forecasts for future load. Many distribution feeders are not equipped to host additional loads that might be introduced from uncoordinated EV charging (charging whenever or wherever) with high EV adoption.

Some initial studies have shown that uncoordinated charging could significantly change load size and shape and introduce higher peaks. This presents Potential Impact No. 1: If the change in load is not considered in distribution planning, the result could be system overloads—when power drawn on a line exceeds the limits of its components. Overloads could cause distribution transformers and lines to overheat if they are not upgraded to handle increased loads. Overheating leads to other challenges.

Potential Impact No. 2 is feeder congestion, wherein distribution and transmission infrastructure is aging and generation and loads are not co-located. Upgrading infrastructure to accommodate added loads can be a costly and time-consuming process.

Potential Impact No. 3 is power quality with lots of uncoordinated charging. If charging loads are not aligned with distributed generation peaks, demand and generation could be mismatched and voltage problems could arise. Voltage dips or spikes equal lower power quality.

Widespread EVs does not have to mean costly upgrades or strains on the grid

We are finding that there are many solutions to mitigate the potential impacts of increased load from super high levels of EVs.

- **Infrastructure upgrades:** Power quality and overloading problems can also be mitigated with careful charging infrastructure planning. Proper planning can minimize the costs of upgrades to extend EV-hosting capacities for both large charging stations and individual vehicle chargers. Placing charging stations on lines with higher capacities and co-locating distributed generation or storage with charging stations could avoid costly feeder upgrades (cha-ching!)—lowering retail rates for customers.
- **Control approaches:** IEEE 1547 requires inverters from distributed generation to be able to do some minimum voltage regulation to allow better interconnection and interoperability between utility electric power systems and DERs. The standard has spurred a lot of progress in this space. The same could also be done on the load side with EVs. Many new proposed EV control schemes manage voltage and congestion impacts of vehicle charging (smart charge management). The control approaches use inverters at charging stations or the EVs themselves to coordinate EV charging, helping to control voltage and maintain frequency on the grid at the charging station location and in the wider area. Looking forward, these systems

may even be able to provide reactive power support as a service.

- **Market solutions:** Market structures could encourage EV drivers to charge at times and locations that work best for the grid, alleviating congestion, voltage, or other local distribution constraints. Market structures include time-of-use rates, real-time pricing, peak use demand charges, and more.

The work continues

Super high adoption of EVs presents many interesting questions that we will continue to study at NREL. For example, NREL's Electric Vehicle Smart Charging at Scale effort is investigating various smart-charging strategies to optimize the benefits and reduce the risks associated with widespread EV adoption. There is also a lot of work being done at the laboratory to understand how to allow equitable access to EVs. Folks who rent or own townhouses or apartments do not have the same access to at-home charging. More charging stations in commercial spaces could encourage workplace charging, which also aligns nicely with solar generation profiles.

Provided by National Renewable Energy Laboratory

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